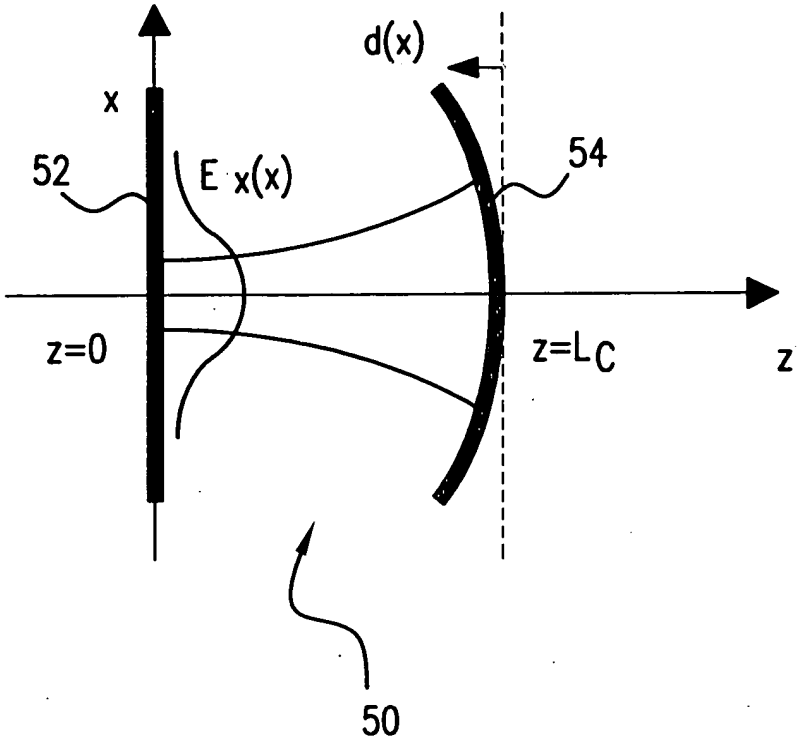
d(x)
x
52
E x(x)
54
z=0
z=Lc
z
50

FIG.1

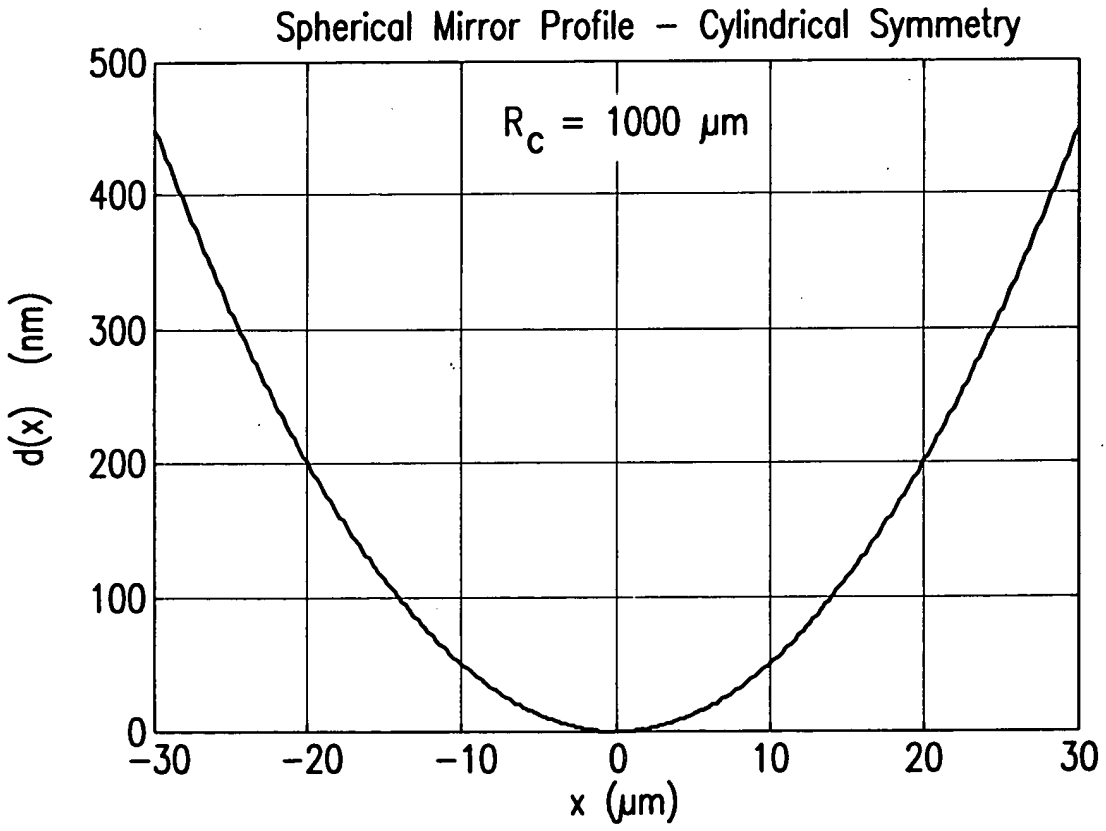
Spherical Mirror Profile – Cylindrical Symmetry
Rc = 1000 μm
d(x) (nm)
500
400
300
200
100
0
−30
−20
−10
0
10
20
30
x (μm)

FIG.2

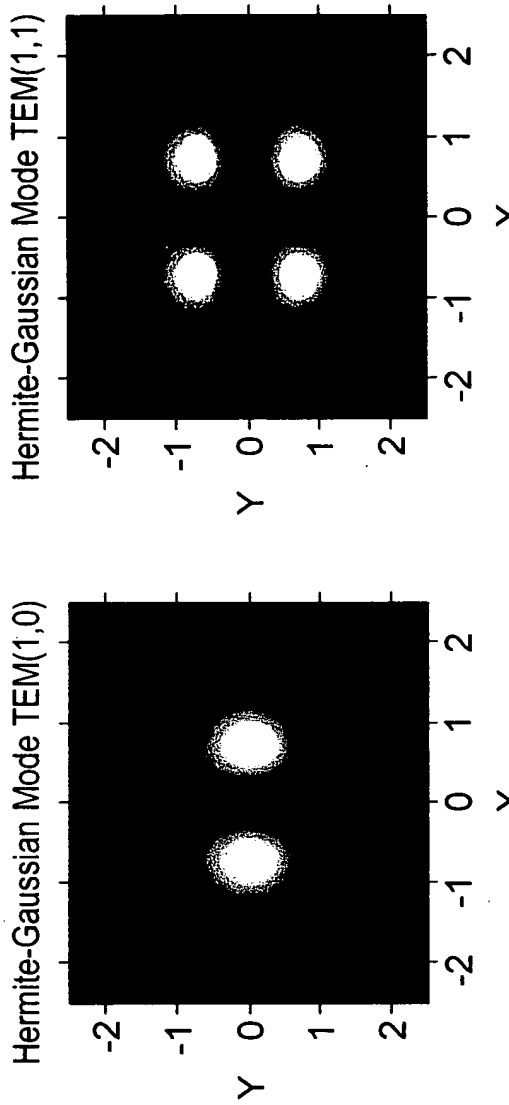

FIG.3A

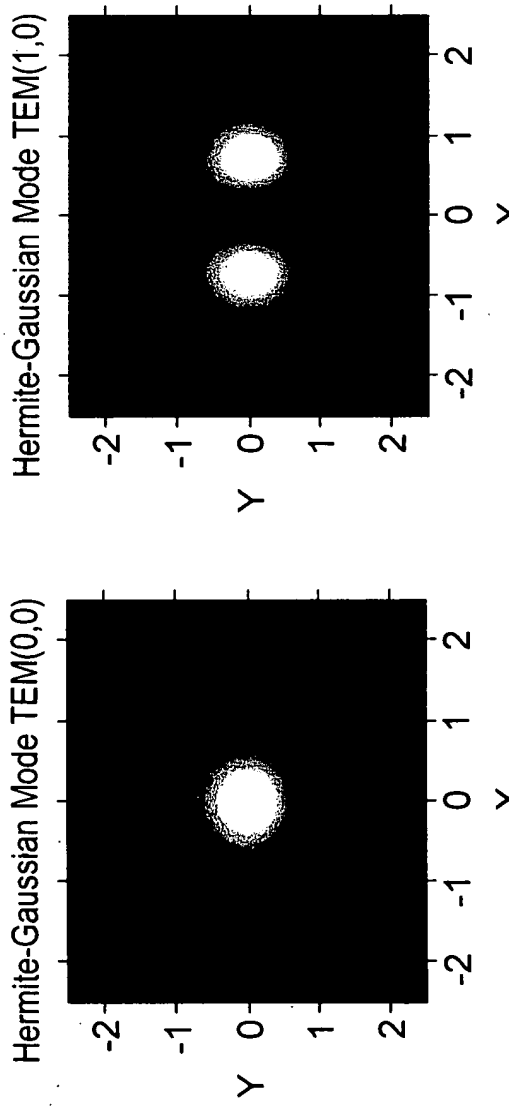

FIG.3B

FIG.3C

FIG.3D

FIG.3E

FIG.3F

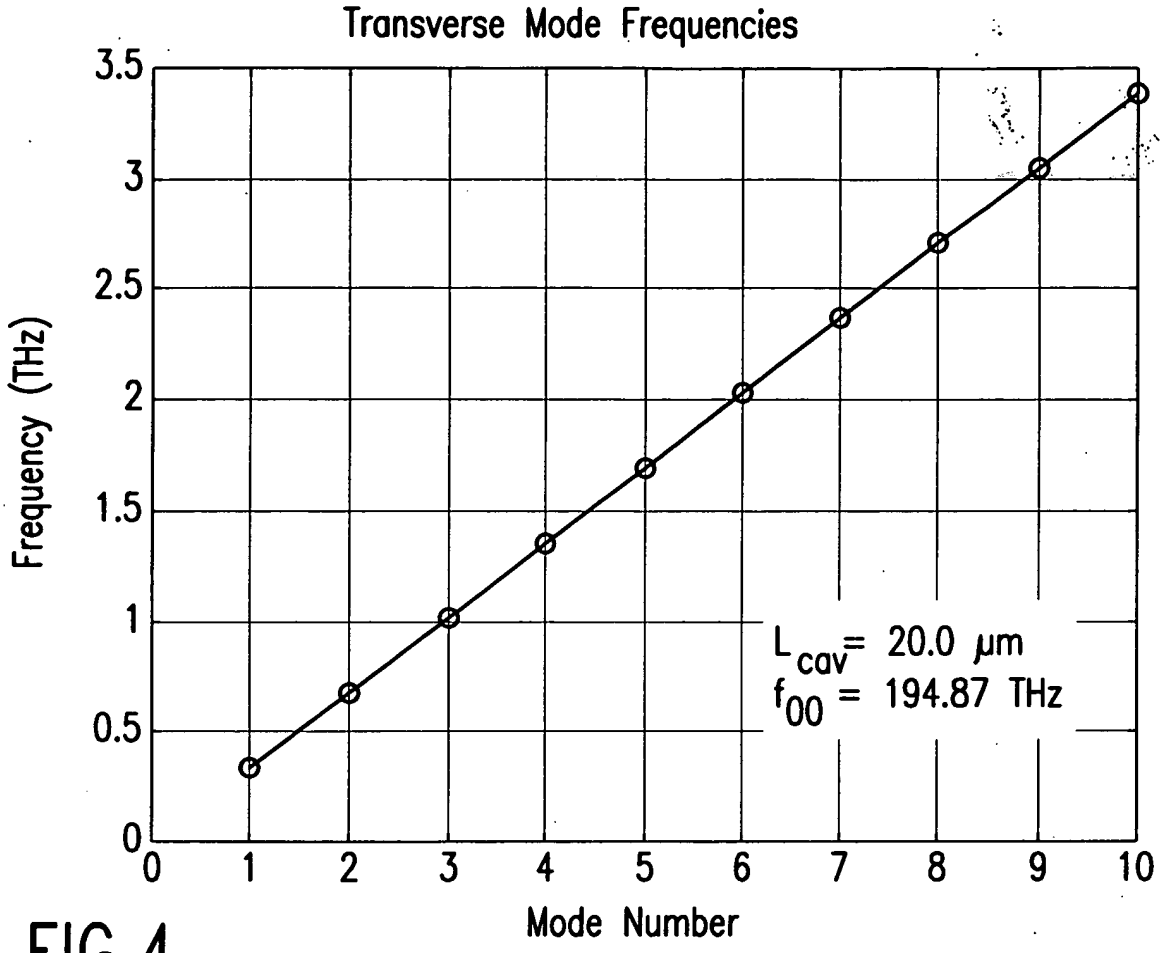
Transverse Mode Frequencies
Frequency (THz)
Mode Number
L_{cav}= 20.0 μm
f_{00} = 194.87 THz
0
0.5
1
1.5
2
2.5
3
3.5
0
1
2
3
4
5
6
7
8
9
10

FIG.4

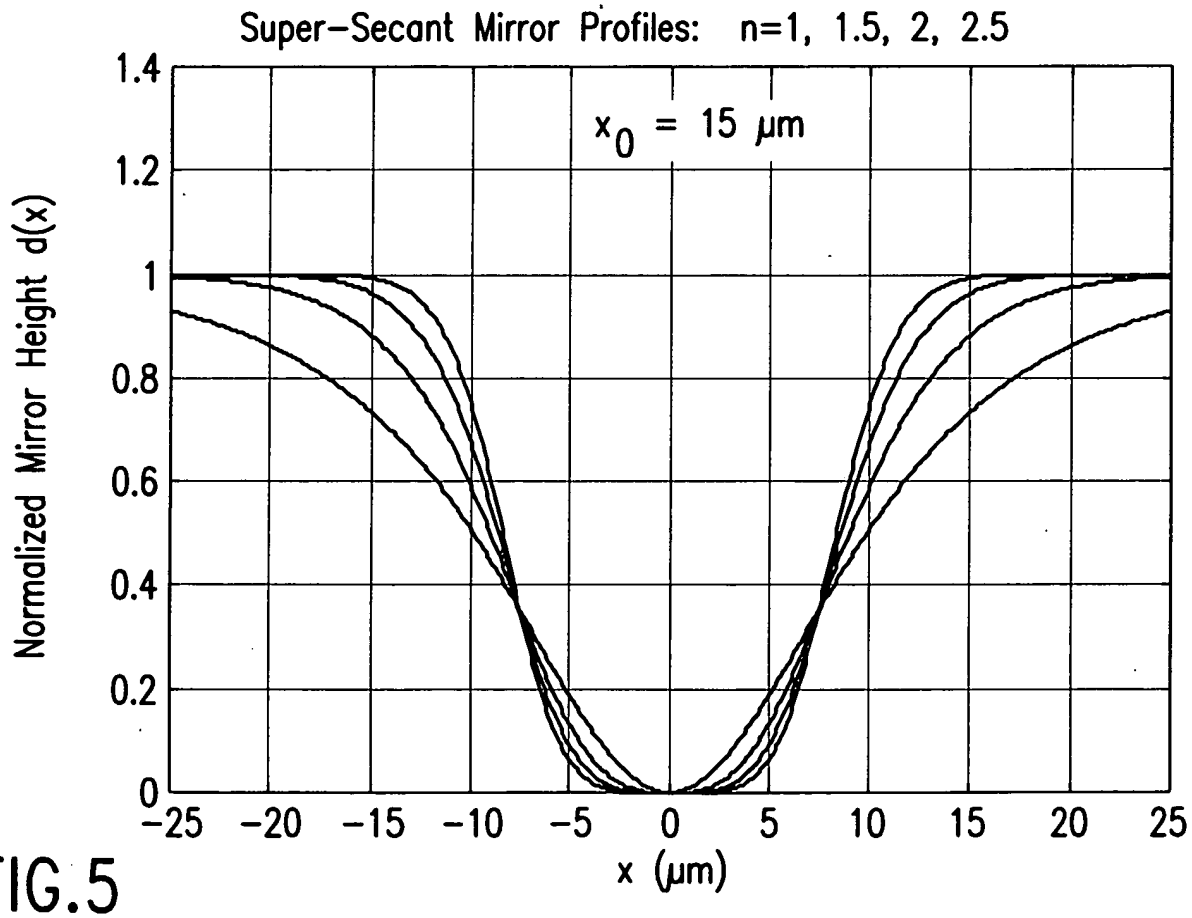
Super−Secant Mirror Profiles: n=1, 1.5, 2, 2.5
x_0 = 15 μm
Normalized Mirror Height d(x)
x (μm)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
−25
−20
−15
−10
−5
0
5
10
15
20
25

FIG.5

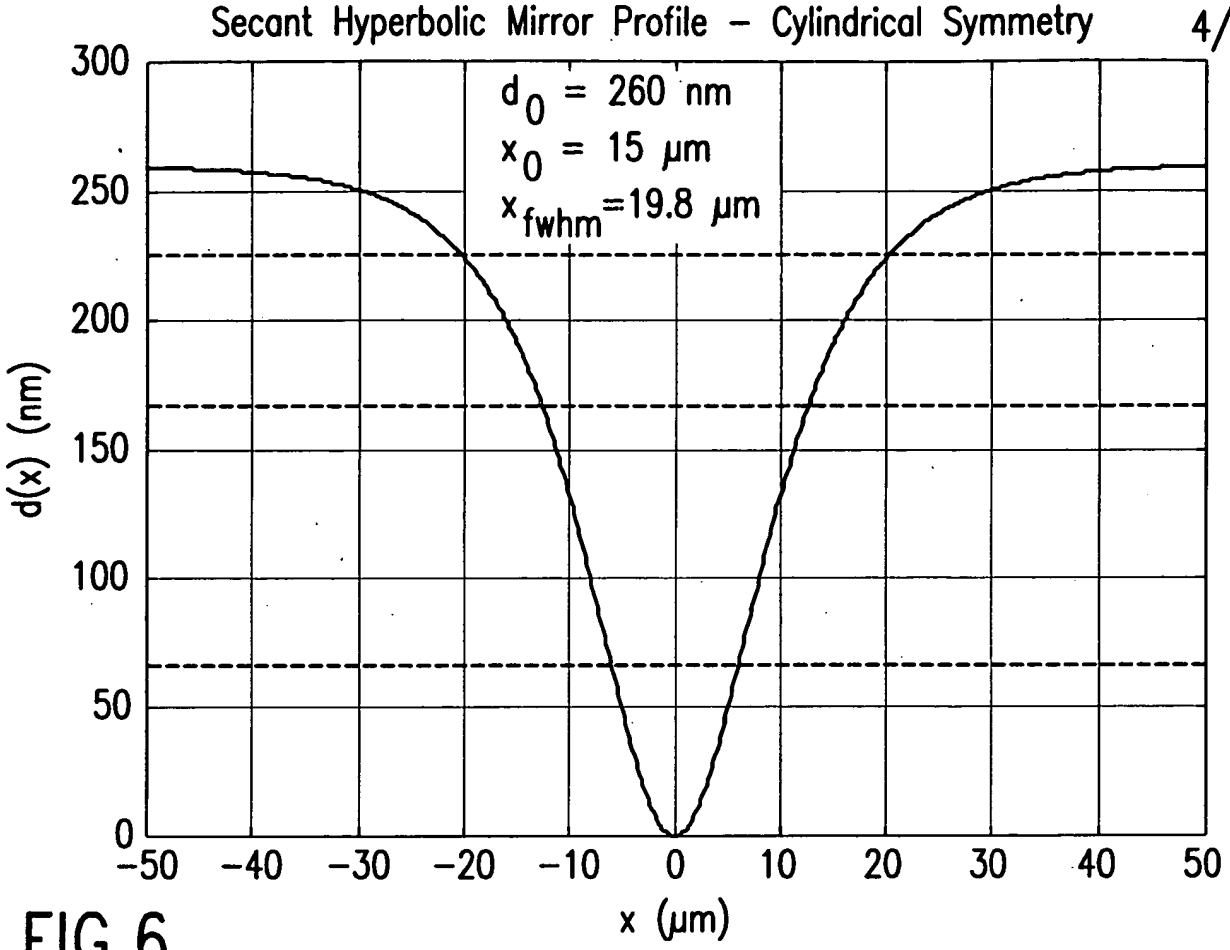
Secant Hyperbolic Mirror Profile – Cylindrical Symmetry
d_0 = 260 nm
x_0 = 15 μm
x_{fwhm}=19.8 μm
d(x) (nm)
x (μm)
300
250
200
150
100
50
0
−50
−40
−30
−20
−10
0
10
20
30
40
50

FIG.6

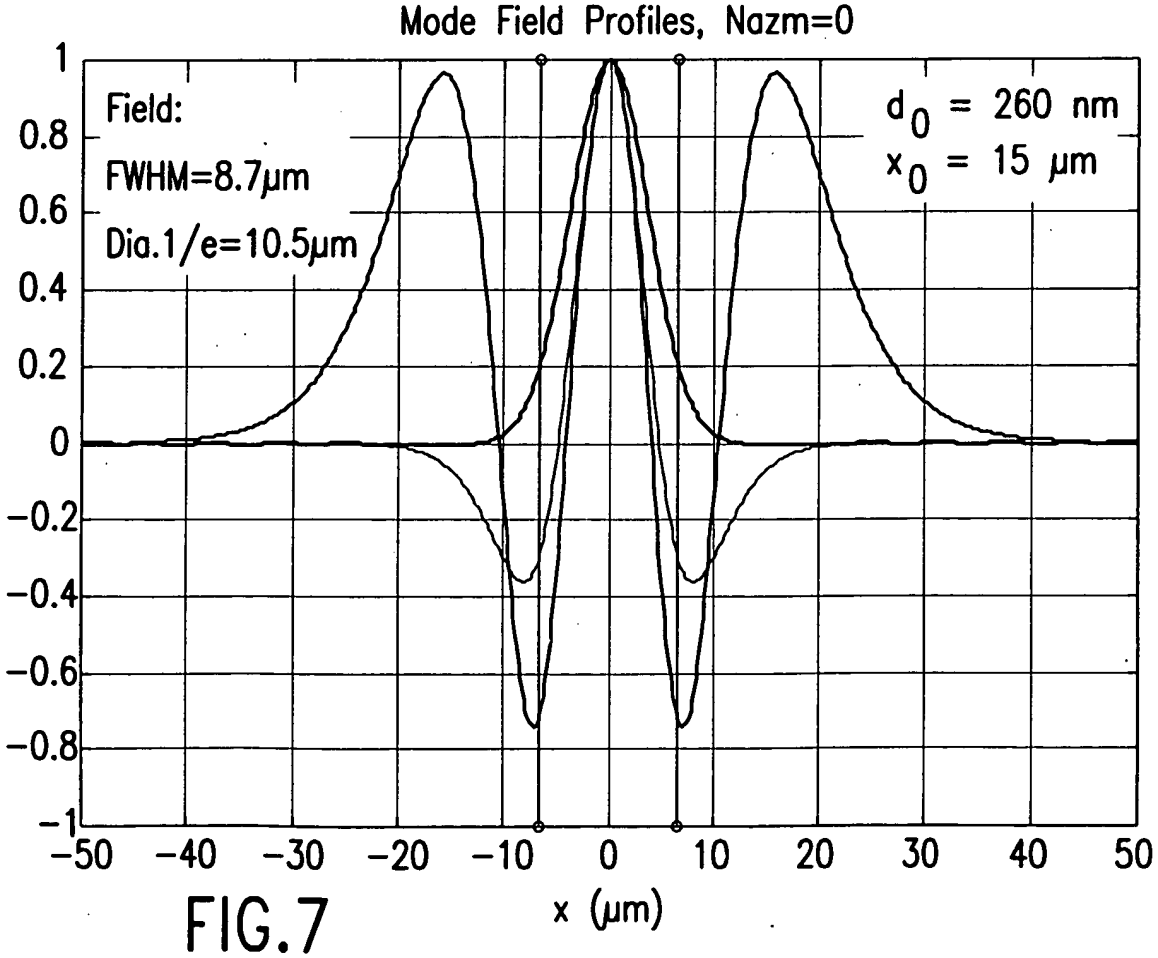
Mode Field Profiles, Nazm=0
Field:
FWHM=8.7μm
Dia.1/e=10.5μm
d_0 = 260 nm
x_0 = 15 μm
x (μm)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−50
−40
−30
−20
−10
0
10
20
30
40
50

FIG.7

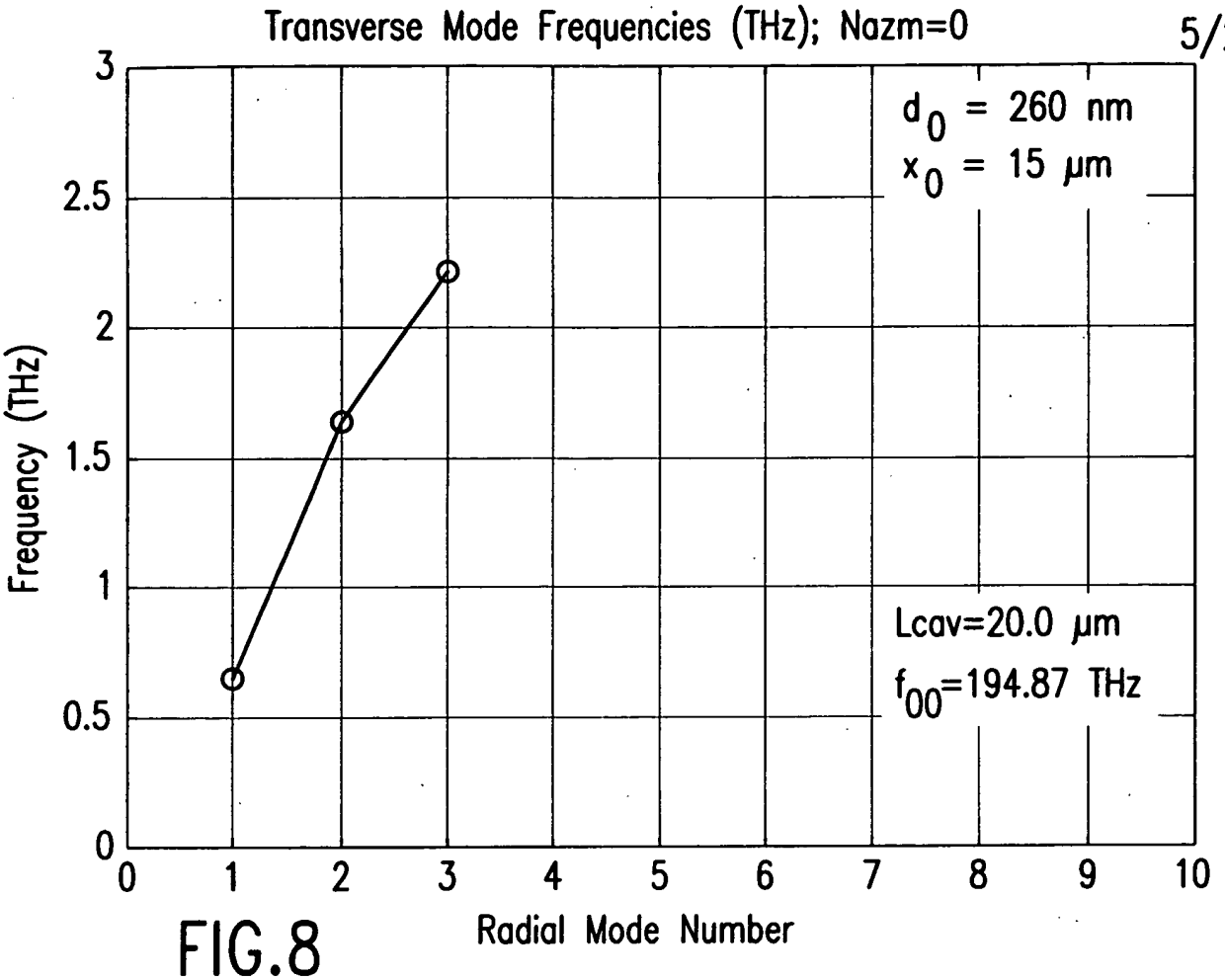
Transverse Mode Frequencies (THz); Nazm=0
d_0 = 260 nm
x_0 = 15 μm
Lcav=20.0 μm
f_{00}=194.87 THz
Frequency (THz)
Radial Mode Number
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
9
10

FIG.8

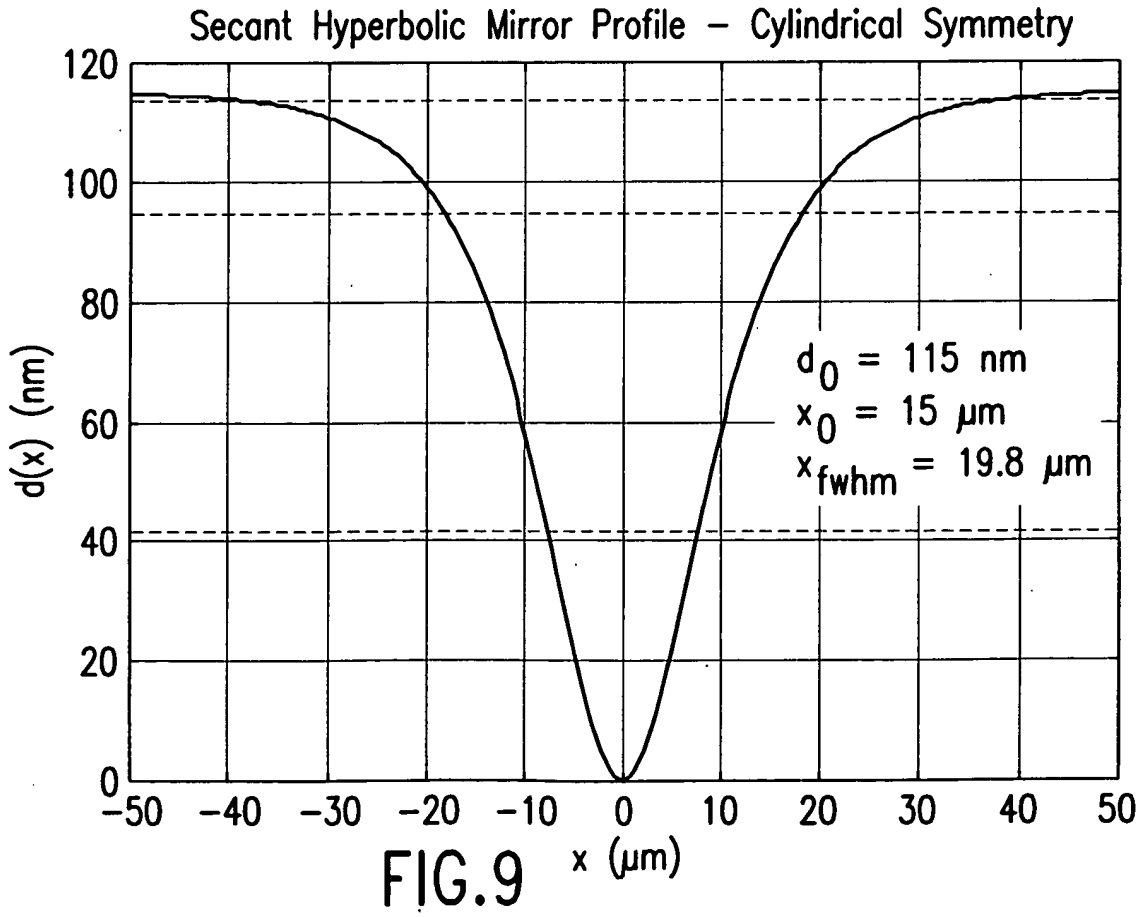
Secant Hyperbolic Mirror Profile – Cylindrical Symmetry
d_0 = 115 nm
x_0 = 15 μm
x_{fwhm} = 19.8 μm
d(x) (nm)
x (μm)
0
20
40
60
80
100
120
−50
−40
−30
−20
−10
0
10
20
30
40
50

FIG.9

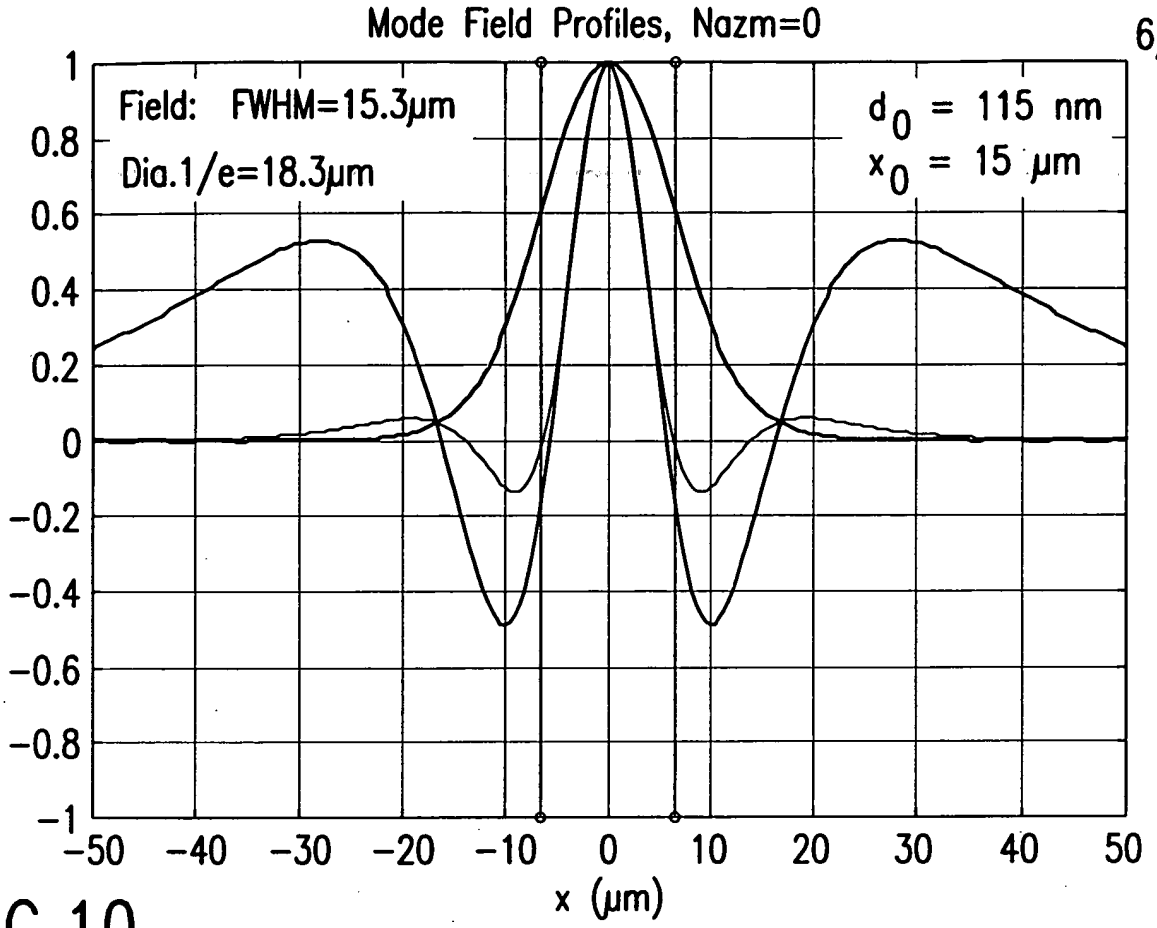
Mode Field Profiles, Nazm=0
Field: FWHM=15.3μm
Dia.1/e=18.3μm
d_0 = 115 nm
x_0 = 15 μm
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−50 −40 −30 −20 −10 0 10 20 30 40 50
x (μm)

FIG.10

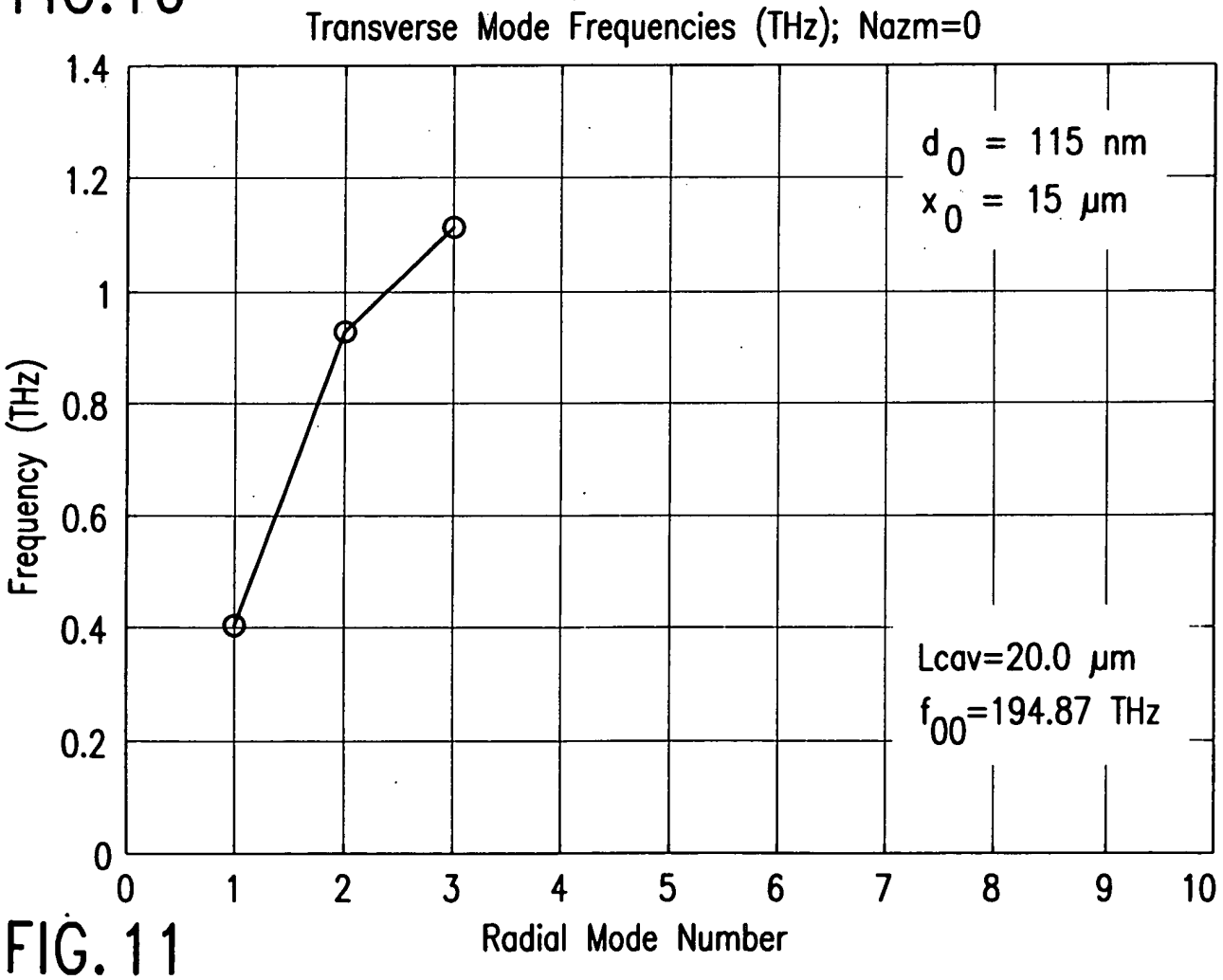
Transverse Mode Frequencies (THz); Nazm=0
d_0 = 115 nm
x_0 = 15 μm
Lcav=20.0 μm
f_{00}=194.87 THz
Frequency (THz)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10
Radial Mode Number

FIG. 11

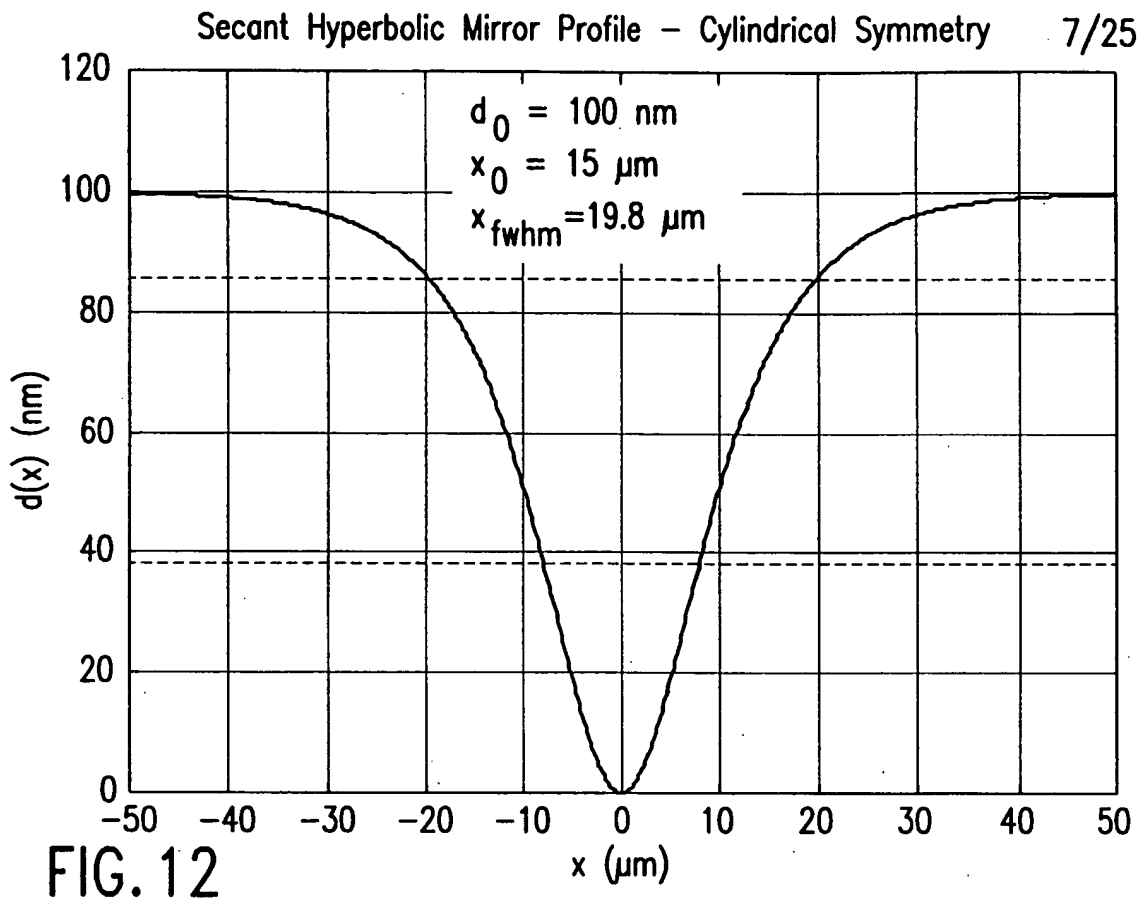
Secant Hyperbolic Mirror Profile – Cylindrical Symmetry
d_0 = 100 nm
x_0 = 15 μm
x_{fwhm}=19.8 μm
d(x) (nm)
x (μm)
120
100
80
60
40
20
0
−50
−40
−30
−20
−10
0
10
20
30
40
50

FIG. 12

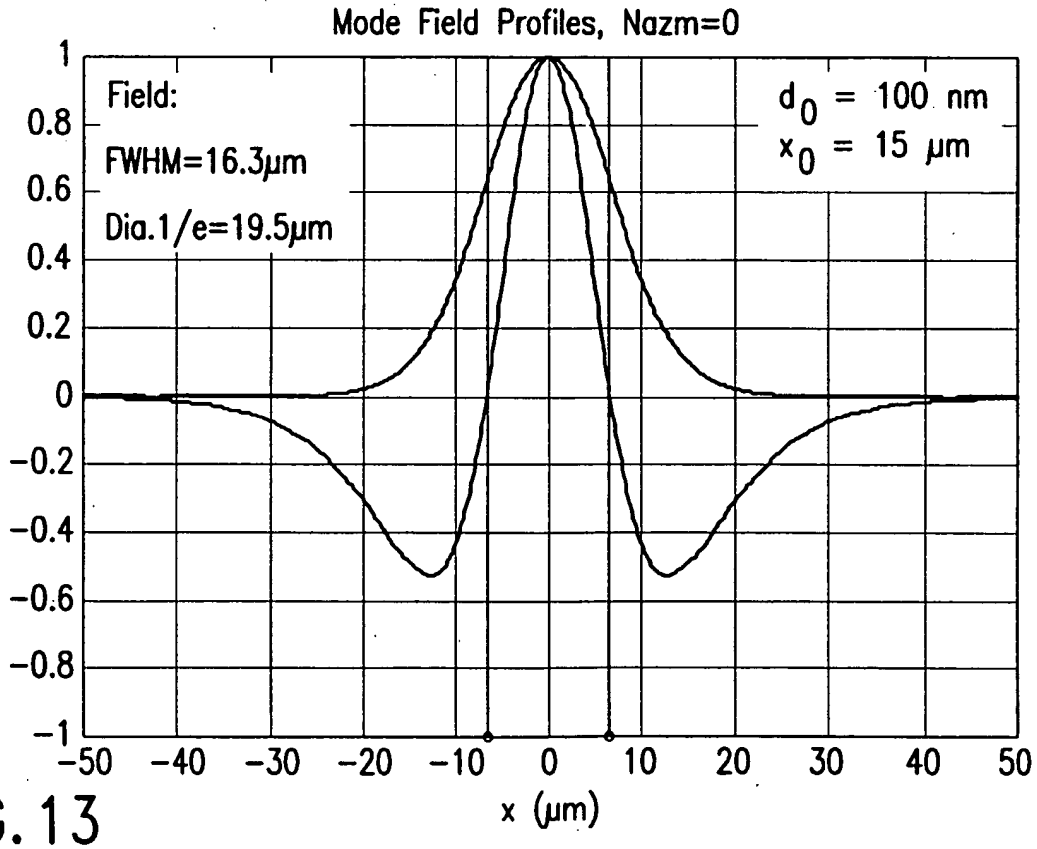
Mode Field Profiles, Nazm=0
Field:
FWHM=16.3μm
Dia.1/e=19.5μm
d_0 = 100 nm
x_0 = 15 μm
x (μm)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−50
−40
−30
−20
−10
0
10
20
30
40
50

FIG. 13

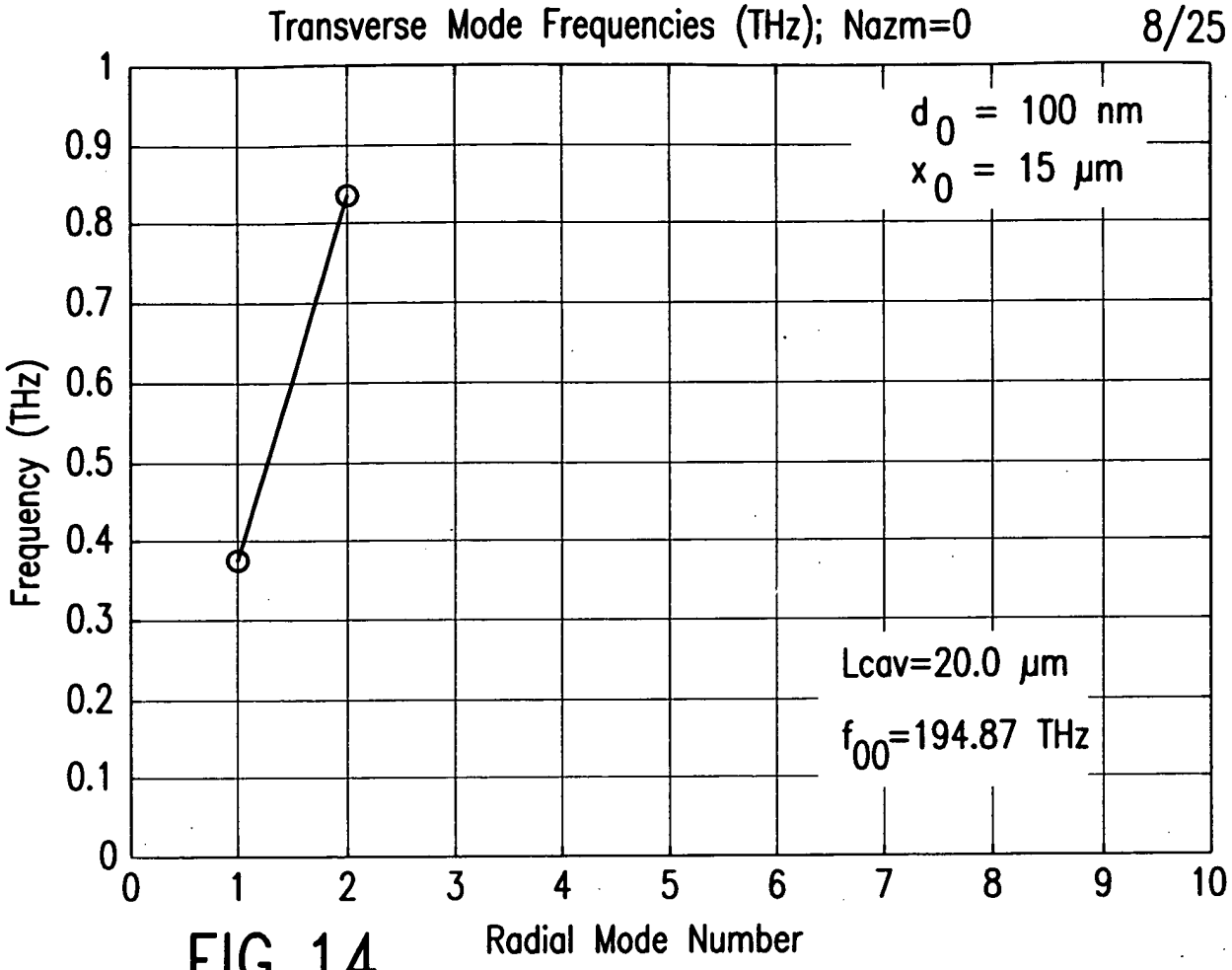
Transverse Mode Frequencies (THz); Nazm=0
d_0 = 100 nm
x_0 = 15 μm
Lcav=20.0 μm
f_{00}=194.87 THz
Frequency (THz)
Radial Mode Number
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 1 2 3 4 5 6 7 8 9 10

FIG. 14

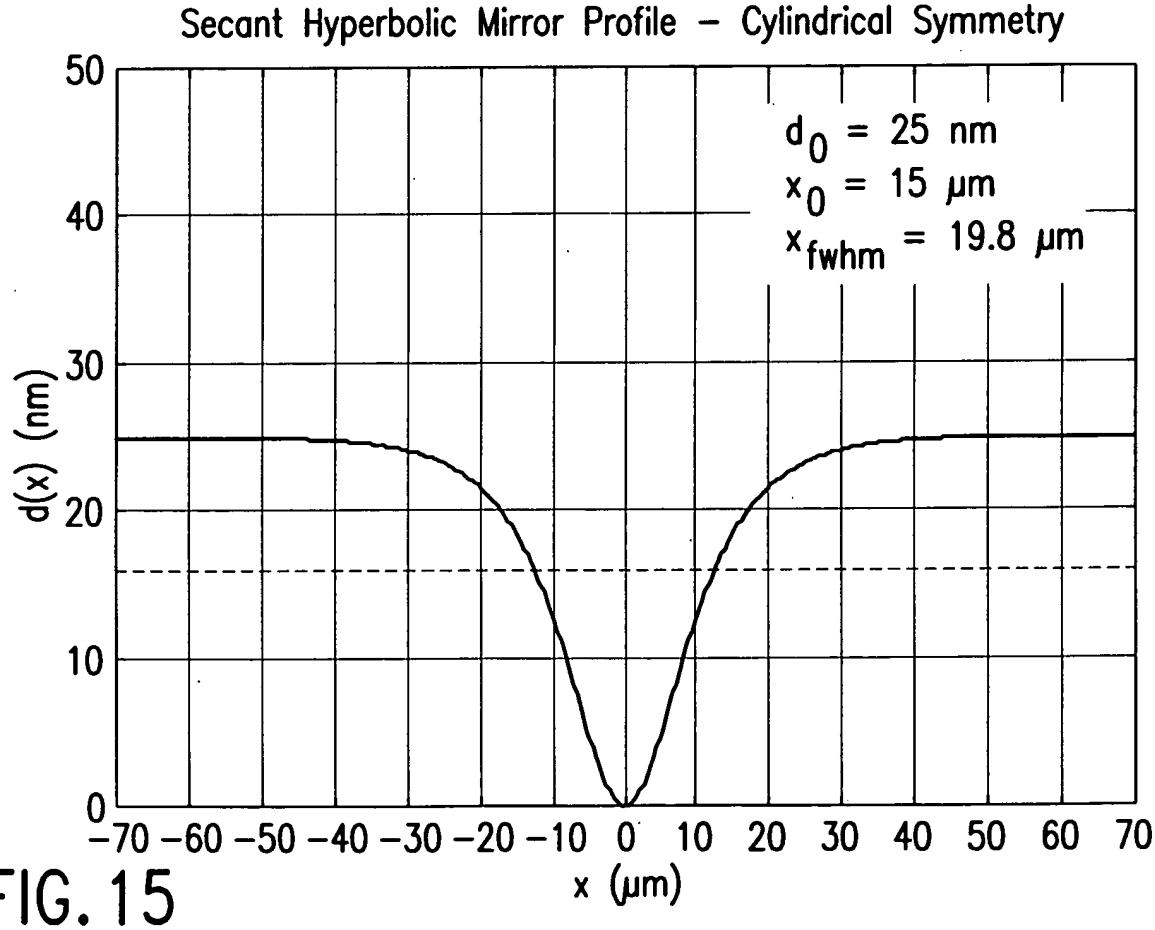
Secant Hyperbolic Mirror Profile – Cylindrical Symmetry
d_0 = 25 nm
x_0 = 15 μm
x_{fwhm} = 19.8 μm
d(x) (nm)
x (μm)
0
10
20
30
40
50
−70 −60 −50 −40 −30 −20 −10 0 10 20 30 40 50 60 70

FIG. 15

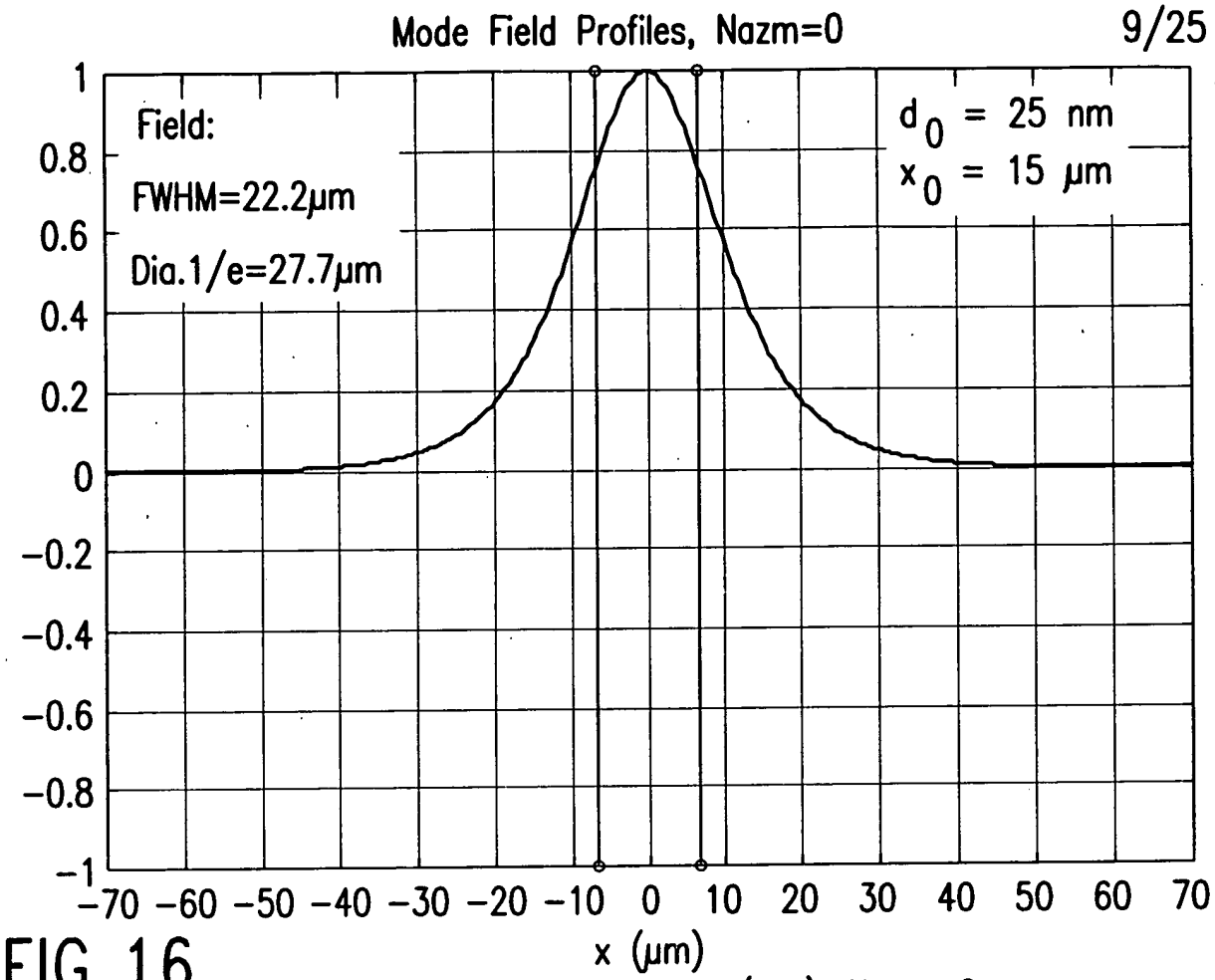
Mode Field Profiles, Nazm=0
Field:
FWHM=22.2μm
Dia.1/e=27.7μm
d_0 = 25 nm
x_0 = 15 μm
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−70 −60 −50 −40 −30 −20 −10 0 10 20 30 40 50 60 70
x (μm)

FIG. 16

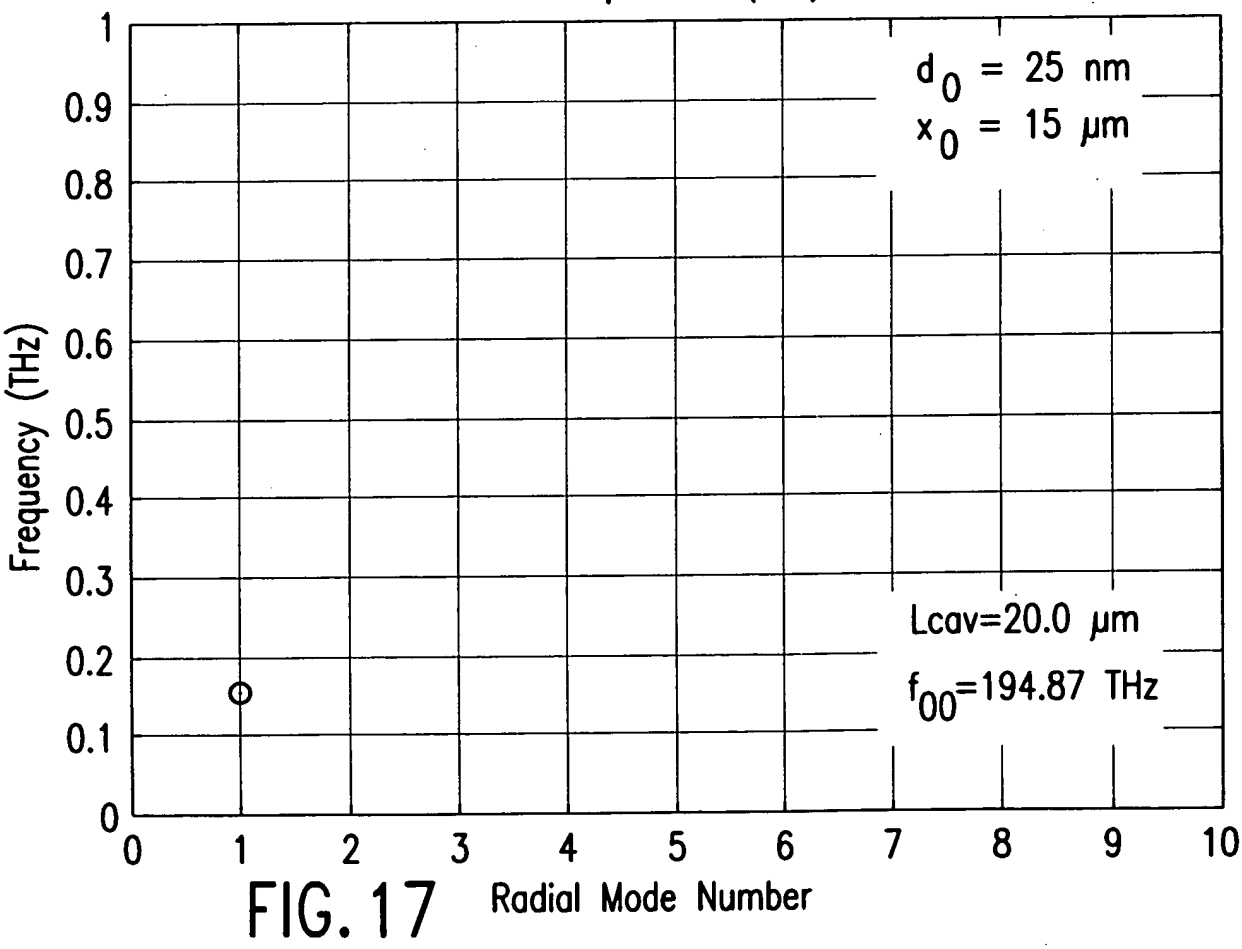
Transverse Mode Frequencies (THz); Nazm=0
d_0 = 25 nm
x_0 = 15 μm
Lcav=20.0 μm
f_{00}=194.87 THz
Frequency (THz)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10
Radial Mode Number

FIG. 17

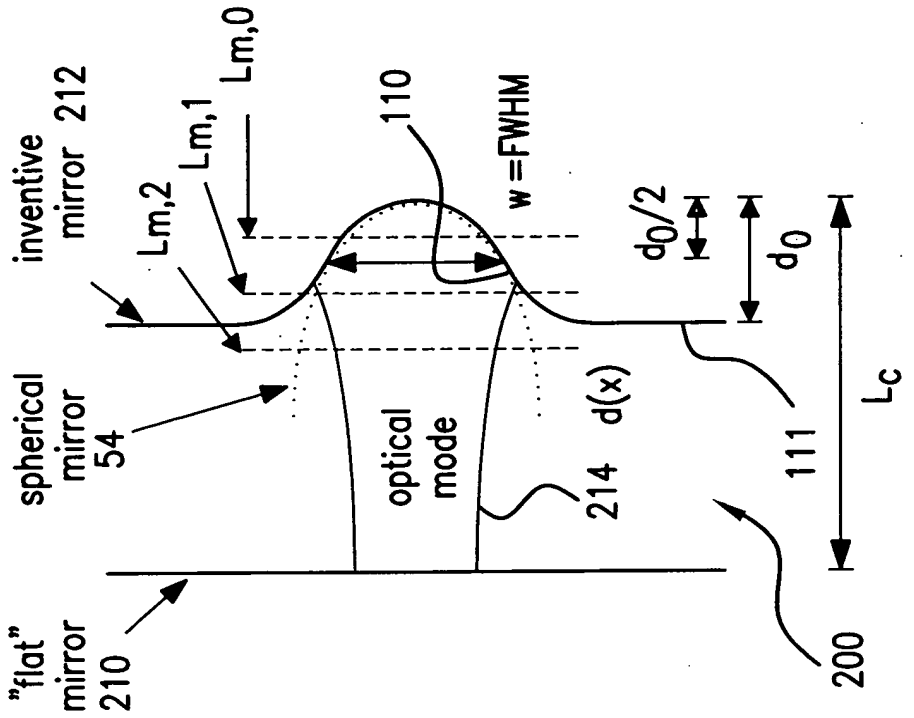
inventive mirror 212
Lm,2
Lm,1
Lm,0
110
w=FWHM
$d_0/2$
d_0
spherical mirror 54
optical mode
214
d(x)
111
L_c
"flat" mirror 210
200

FIG. 19

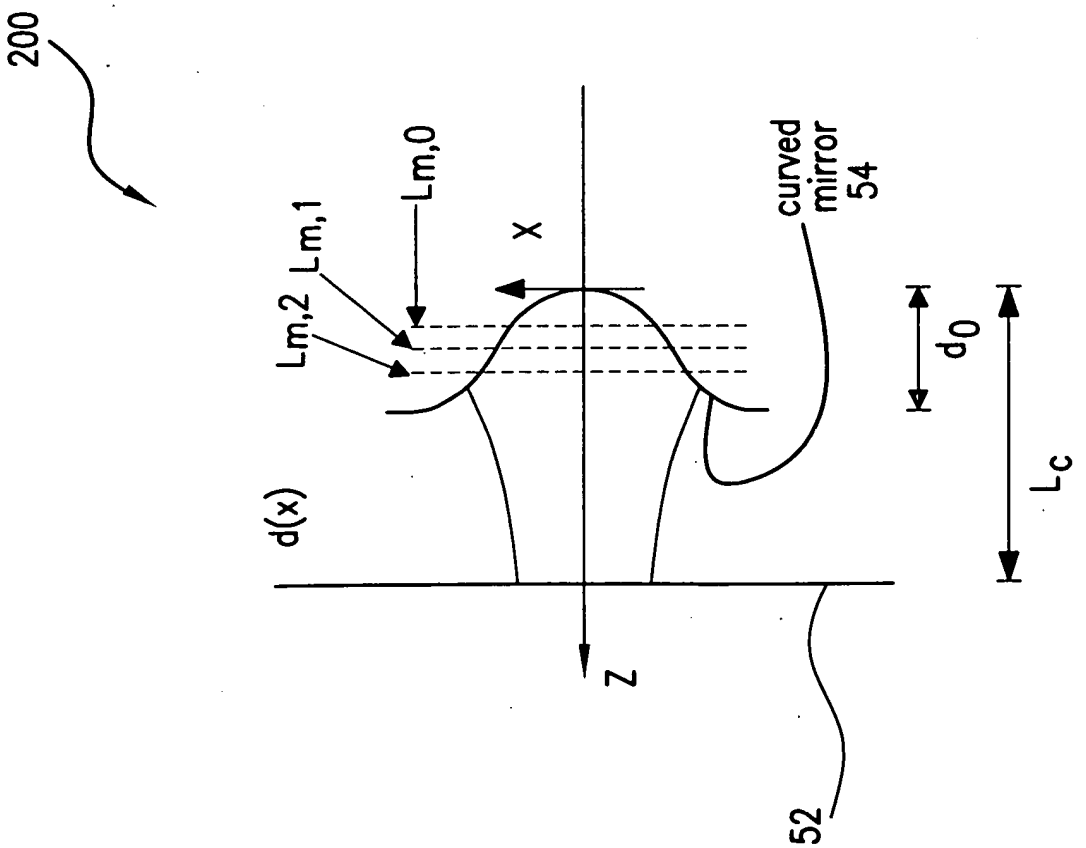
200
Lm,0
Lm,1
Lm,2
X
curved mirror 54
d_0
L_c
d(x)
Z
52

FIG. 18

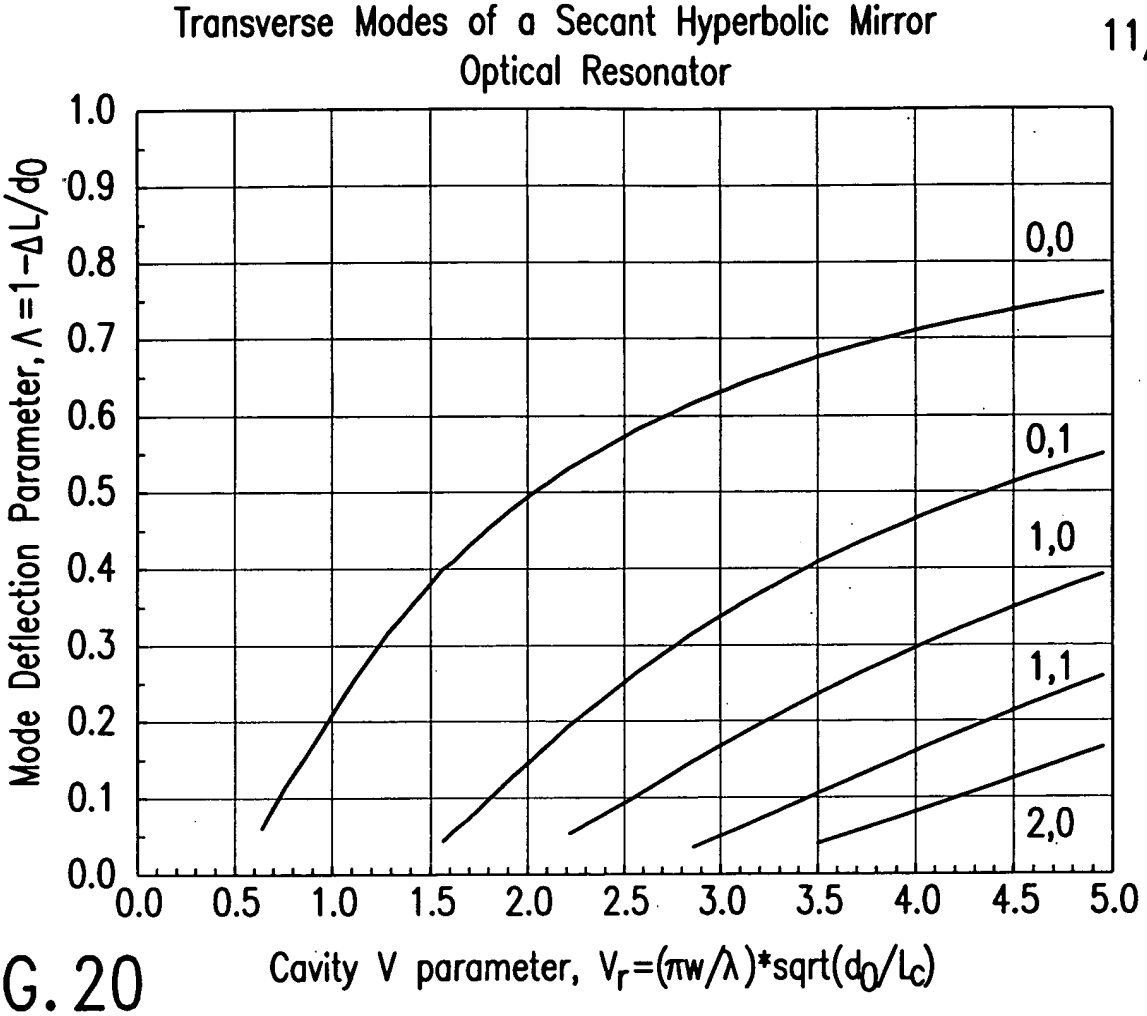
Transverse Modes of a Secant Hyperbolic Mirror Optical Resonator
Mode Deflection Parameter, Λ=1-ΔL/d0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0,0
0,1
1,0
1,1
2,0
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Cavity V parameter, Vr=(πw/λ)*sqrt(d0/Lc)

FIG. 20

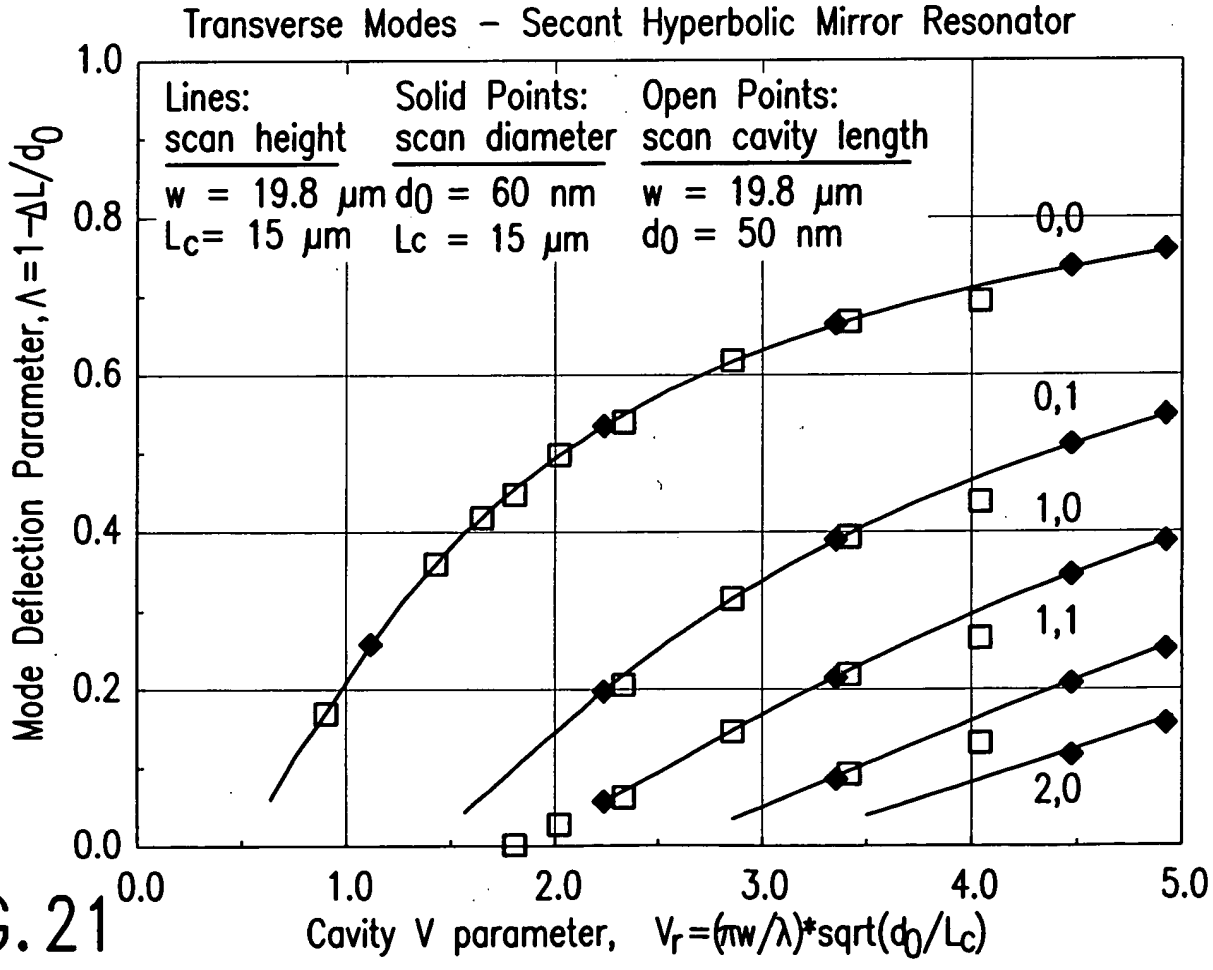
Transverse Modes – Secant Hyperbolic Mirror Resonator
Lines: scan height
w = 19.8 μm
Lc = 15 μm
Solid Points: scan diameter
d0 = 60 nm
Lc = 15 μm
Open Points: scan cavity length
w = 19.8 μm
d0 = 50 nm
Mode Deflection Parameter, Λ=1-ΔL/d0
1.0
0.8
0.6
0.4
0.2
0.0
0,0
0,1
1,0
1,1
2,0
0.0 1.0 2.0 3.0 4.0 5.0
Cavity V parameter, Vr=(πw/λ)*sqrt(d0/Lc)

FIG. 21

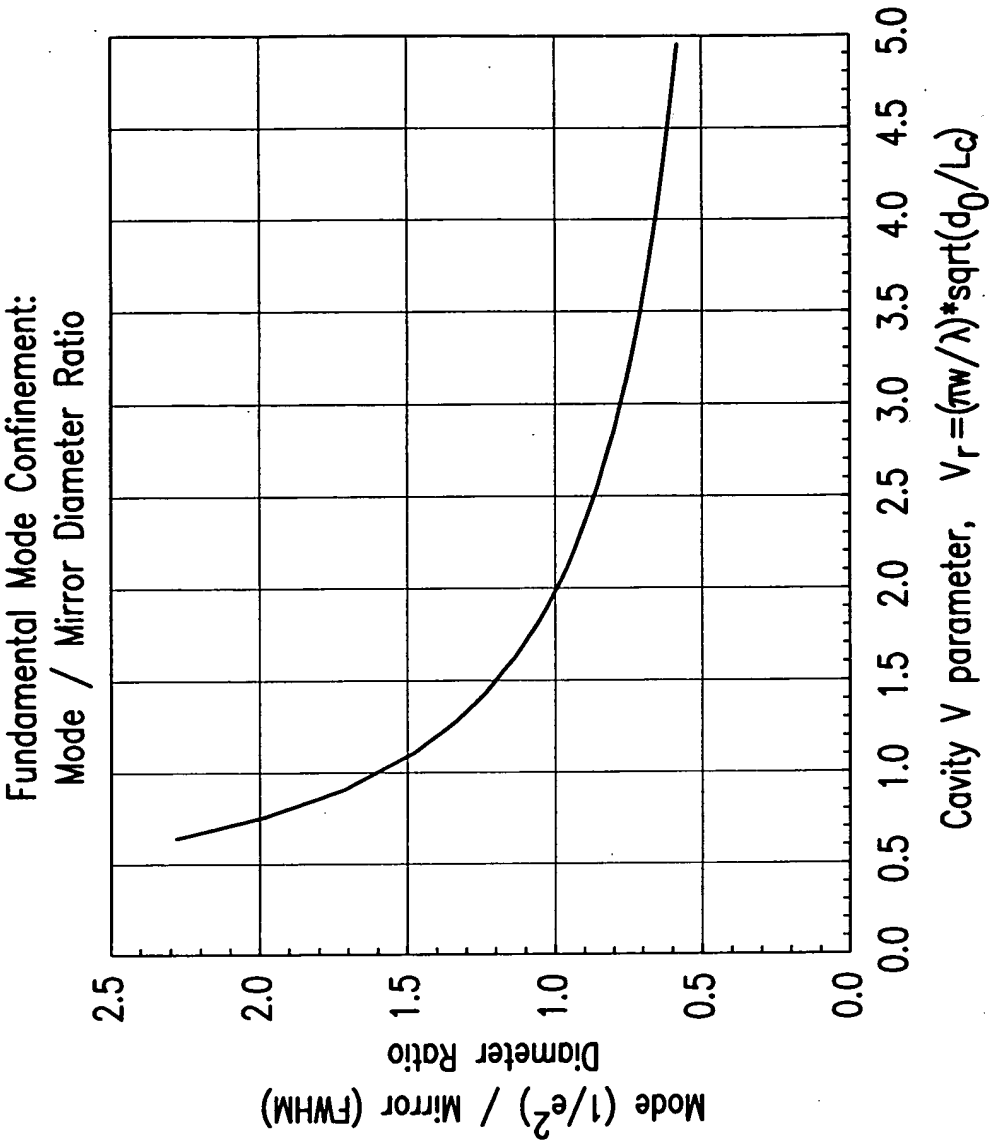
Fundamental Mode Confinement:
Mode / Mirror Diameter Ratio
Mode (1/e²) / Mirror (FWHM)
Diameter Ratio
2.5
2.0
1.5
1.0
0.5
0.0
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Cavity V parameter, $V_r=(\pi w/\lambda)*sqrt(d_0/L_c)$

FIG. 23

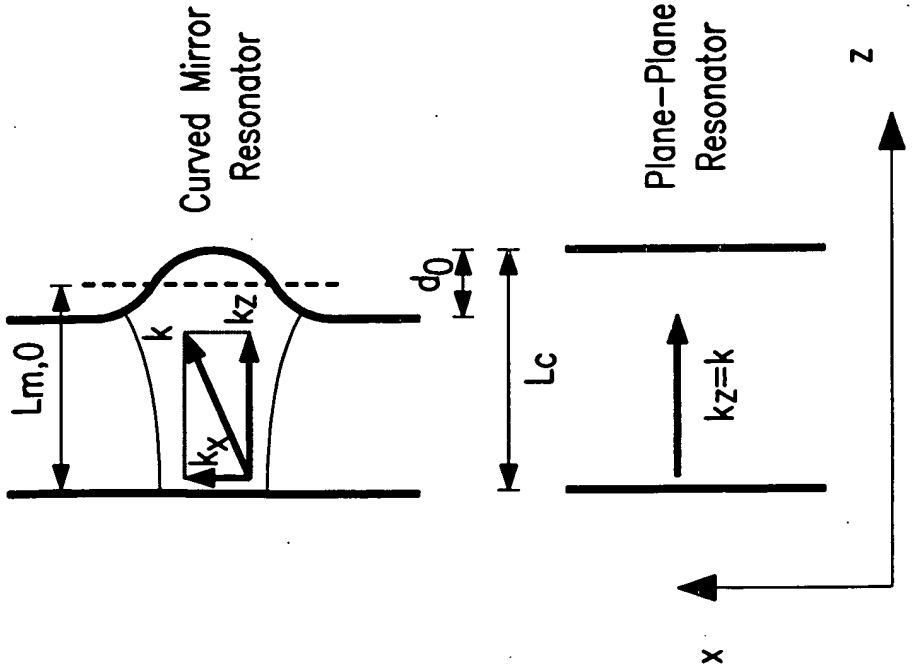
Curved Mirror
Resonator
Plane–Plane
Resonator
Lm,0
k
kz
kx
d0
Lc
kz=k
z
x

FIG. 22

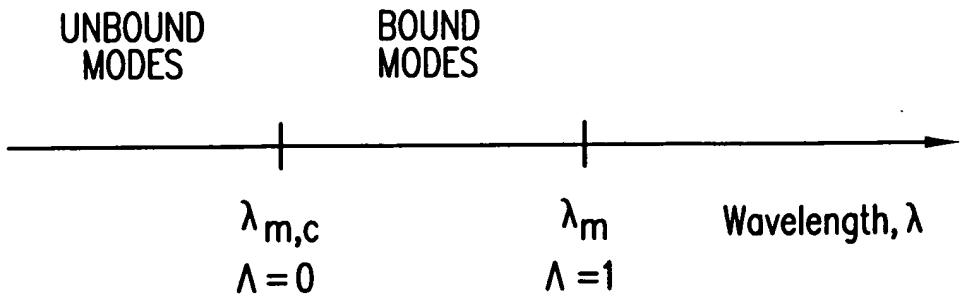
UNBOUND MODES
BOUND MODES
λm,c
Λ=0
λm
Λ=1
Wavelength, λ

FIG. 24

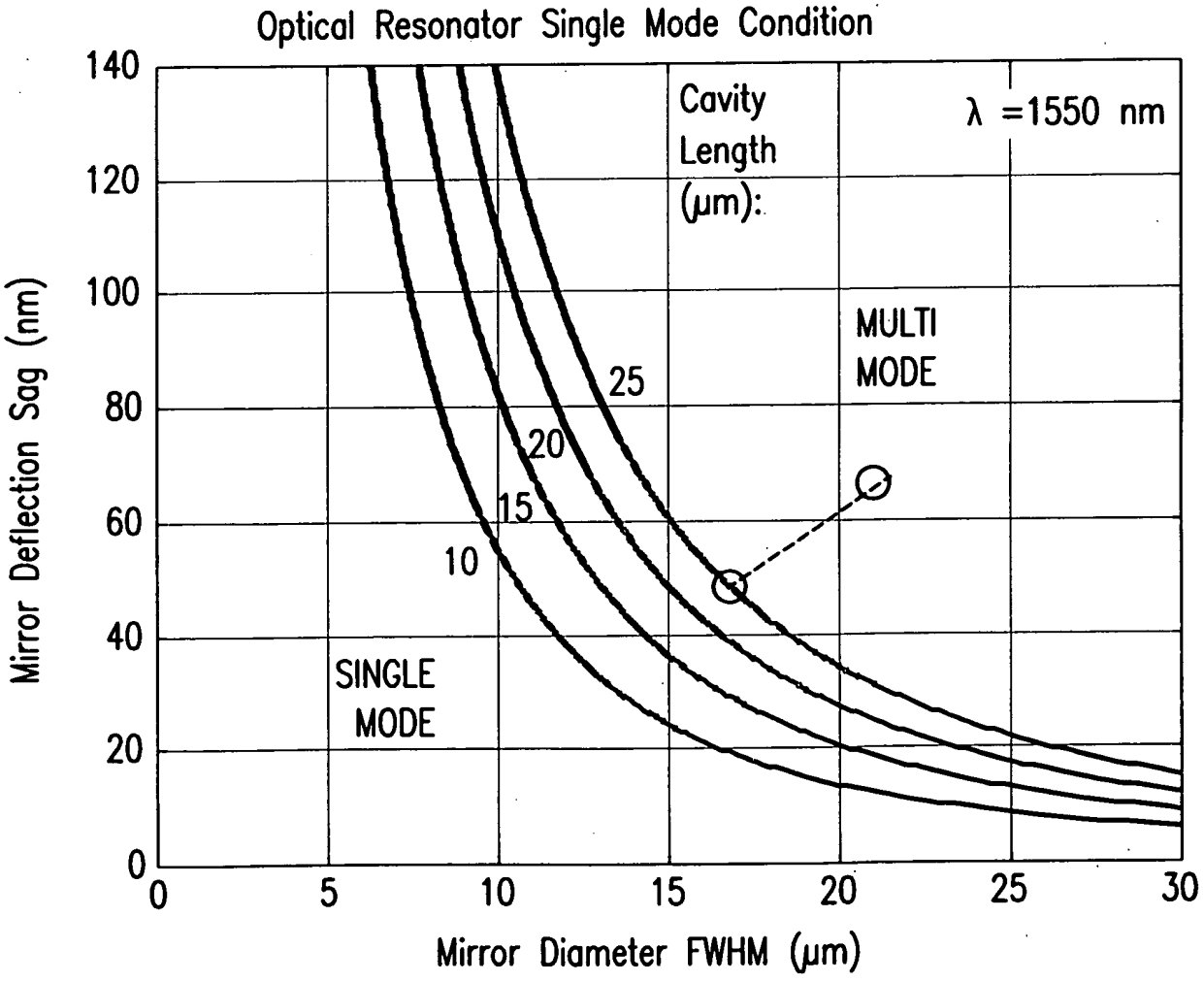
Optical Resonator Single Mode Condition
Cavity Length (μm):
λ =1550 nm
MULTI MODE
SINGLE MODE
25
20
15
10
Mirror Deflection Sag (nm)
Mirror Diameter FWHM (μm)
0
20
40
60
80
100
120
140
0
5
10
15
20
25
30

FIG. 25

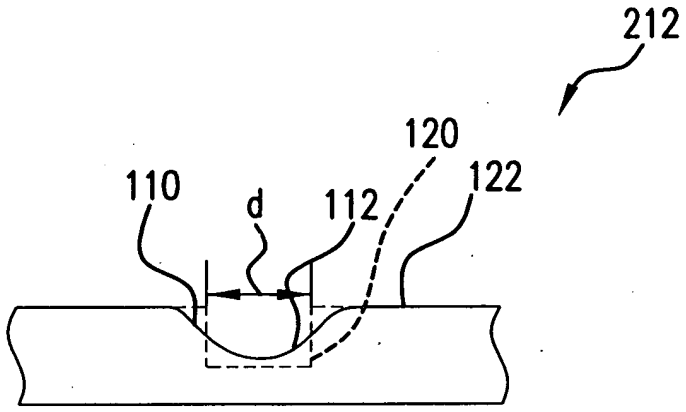

FIG. 26

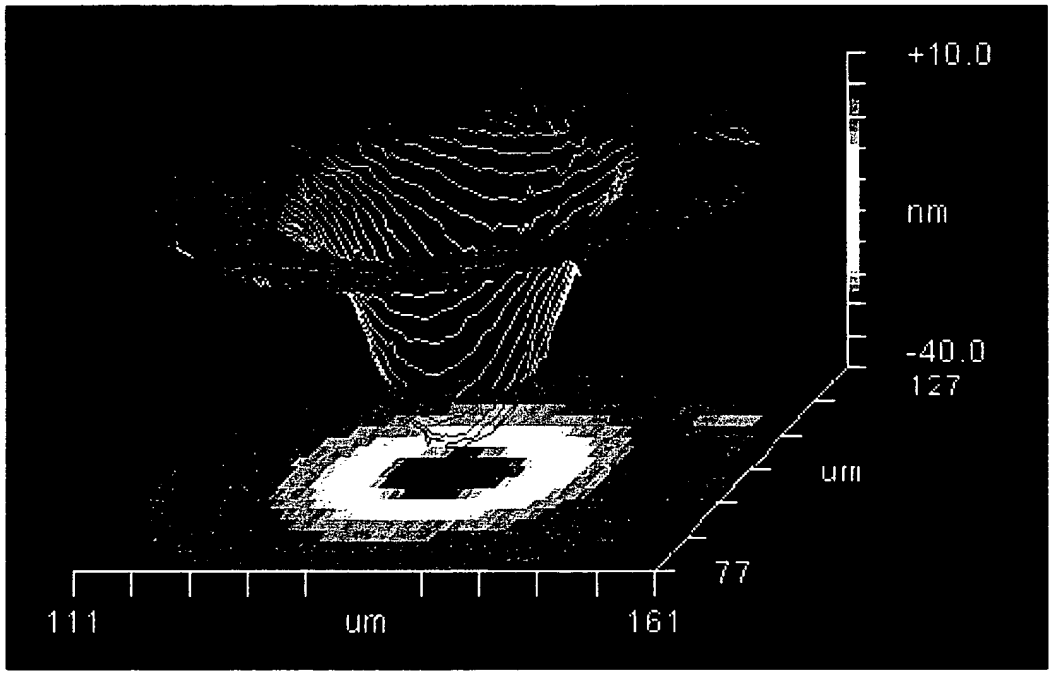

FIG.27A

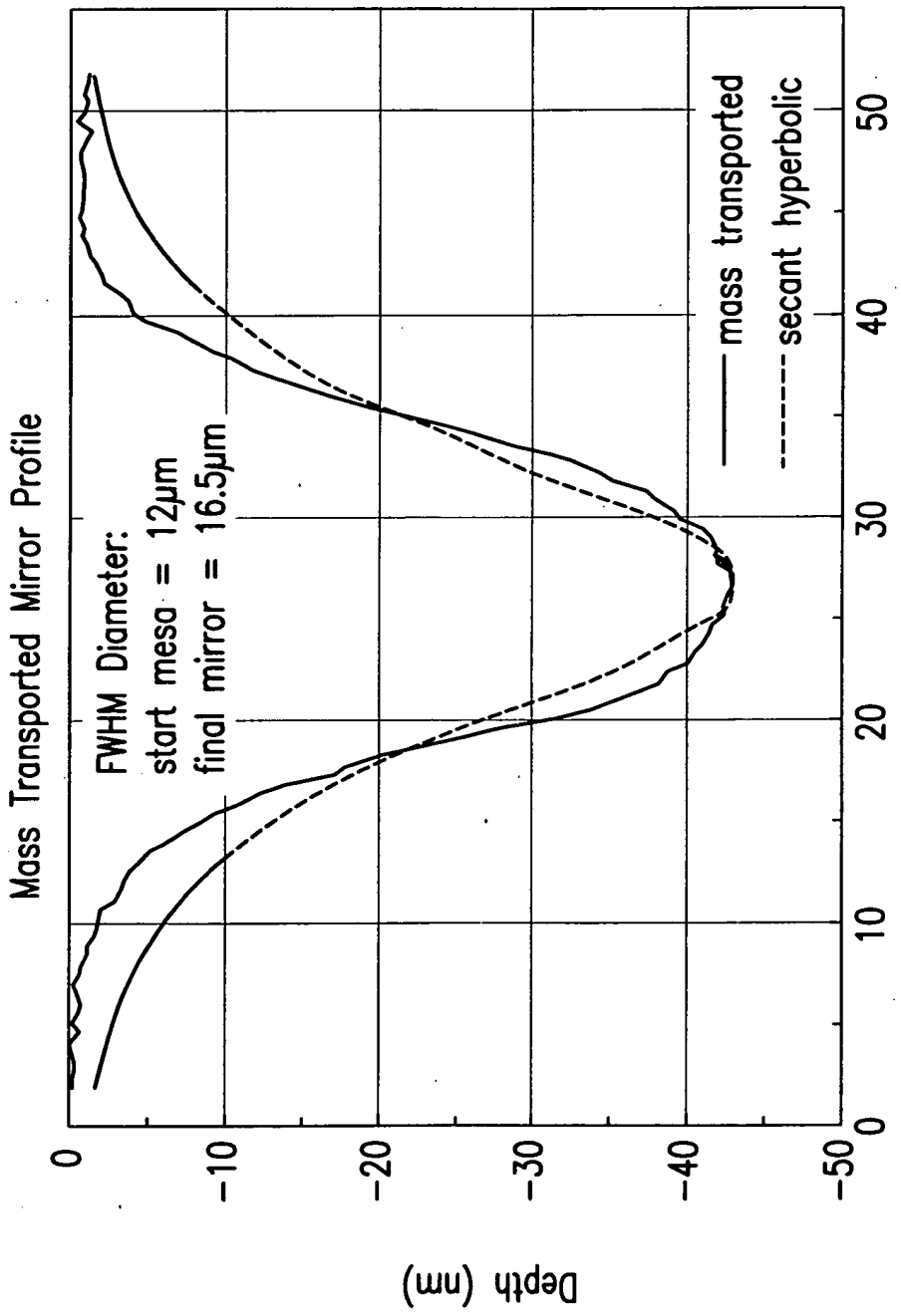
Mass Transported Mirror Profile
FWHM Diameter:
start mesa = 12μm
final mirror = 16.5μm
mass transported
secant hyperbolic
Depth (nm)
Distance (μm)
0
-10
-20
-30
-40
-50
0
10
20
30
40
50

FIG. 27B

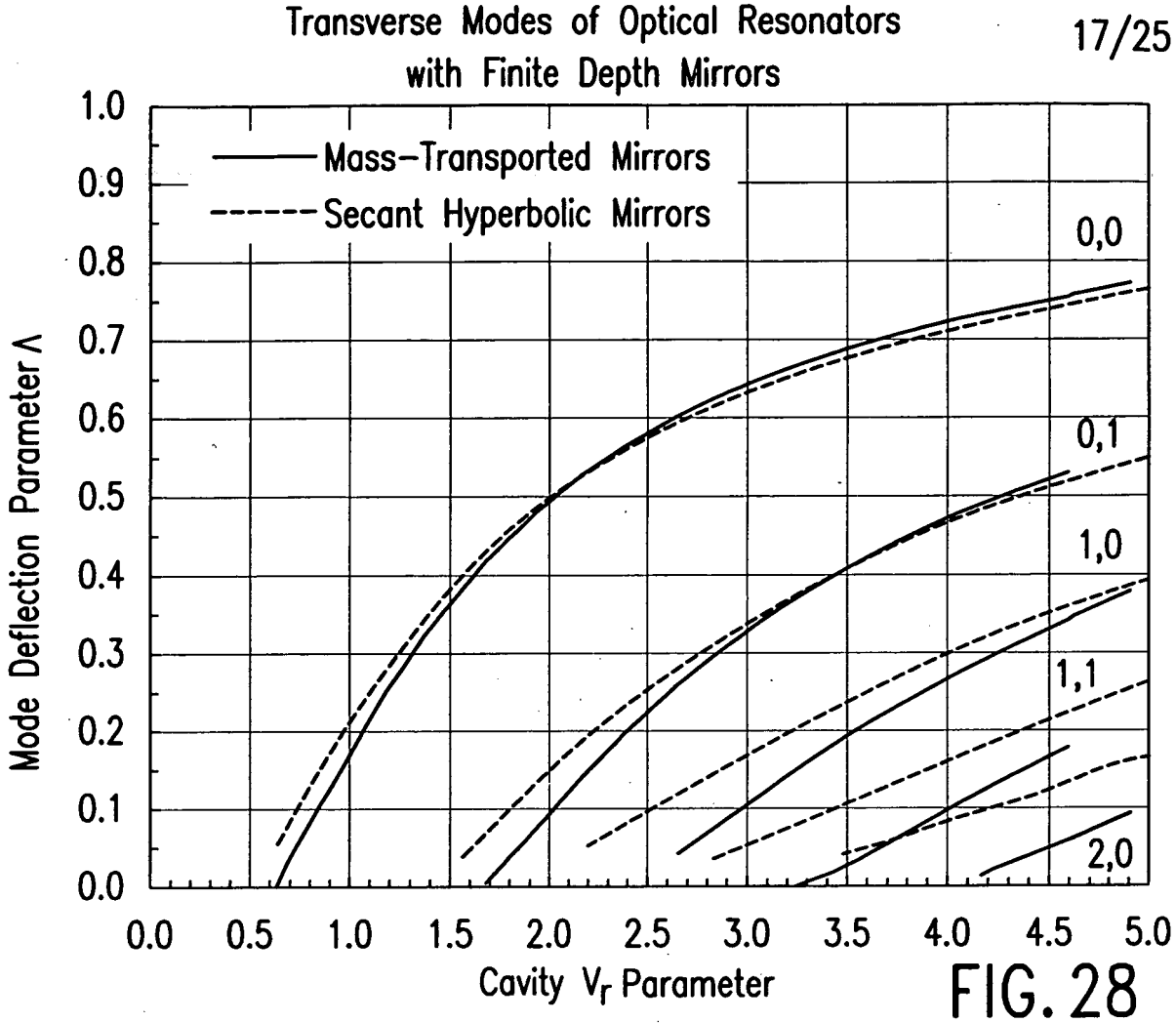

FIG. 28

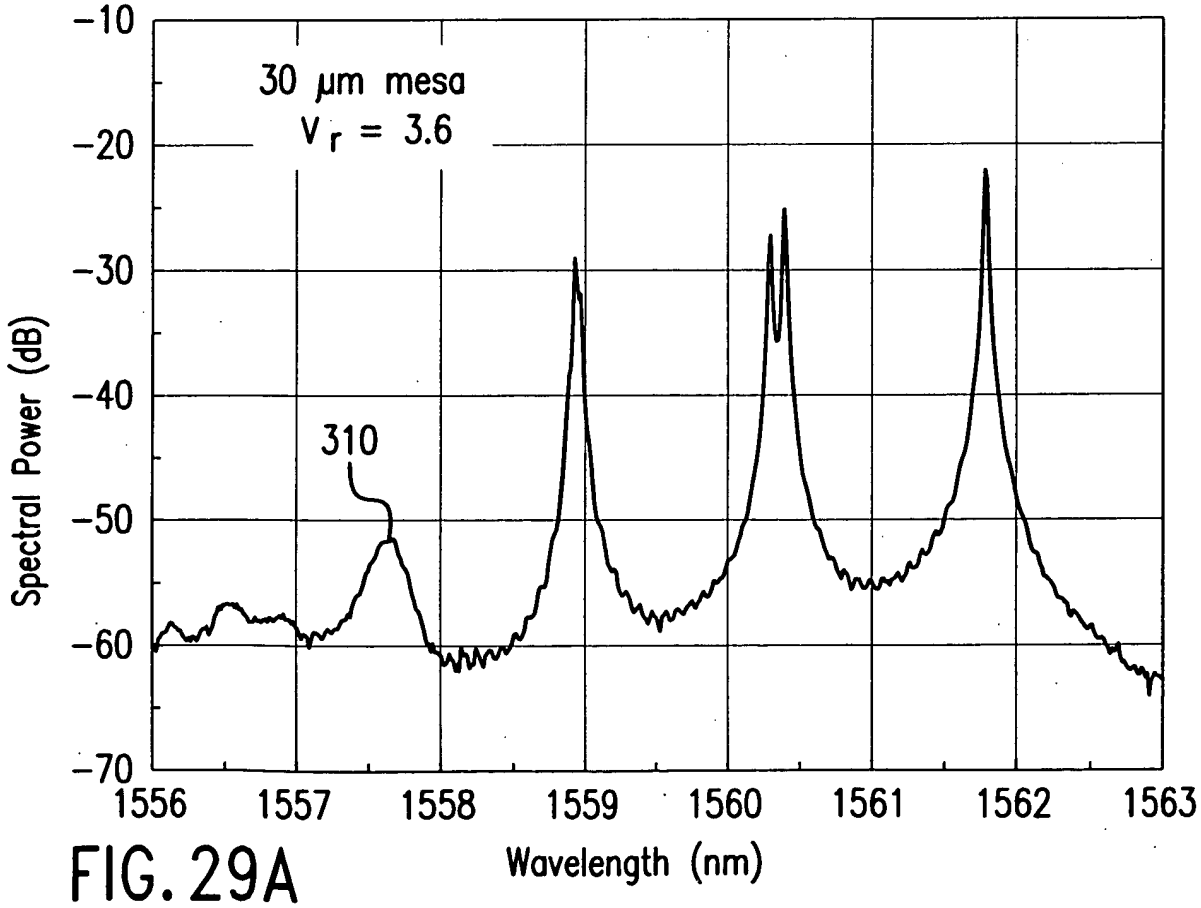

FIG. 29A

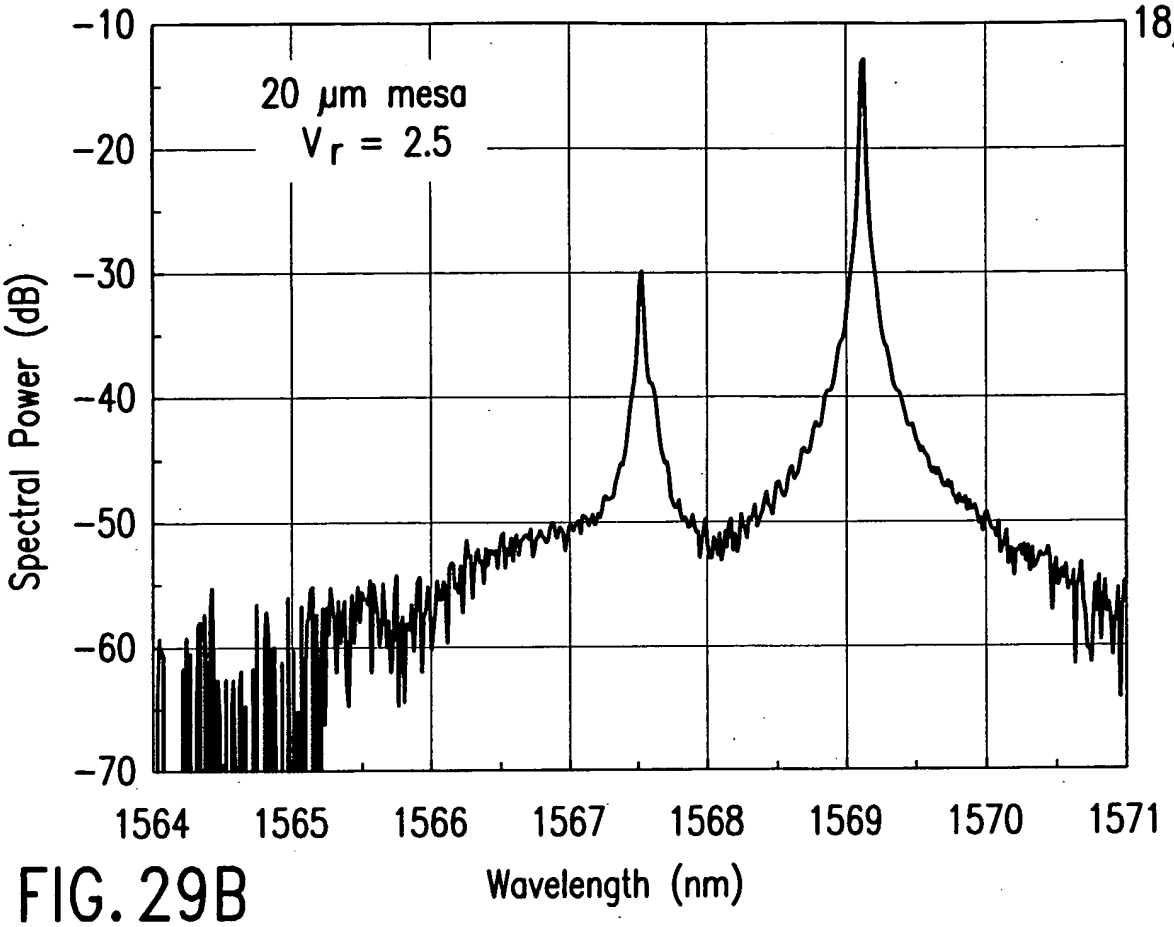

FIG. 29B

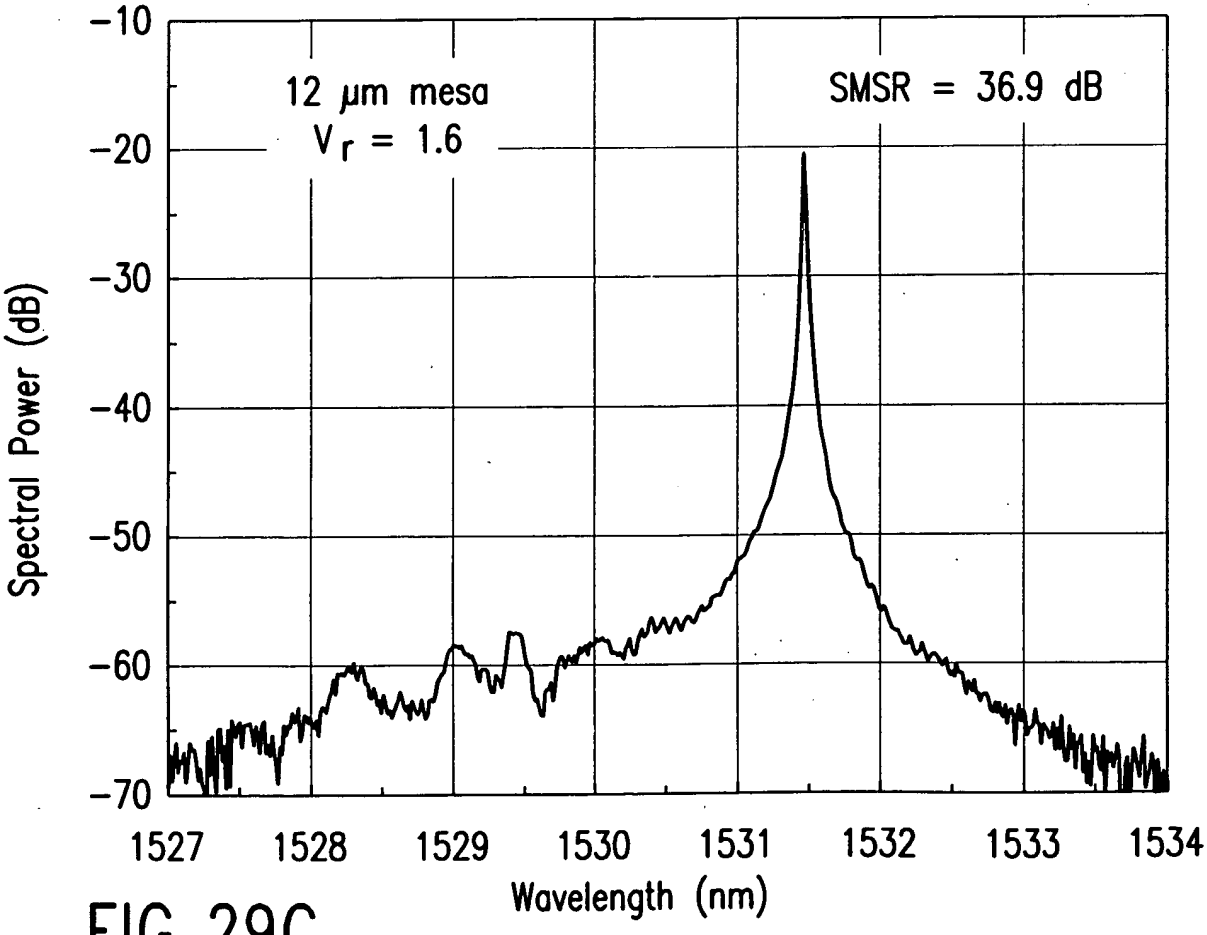

FIG. 29C

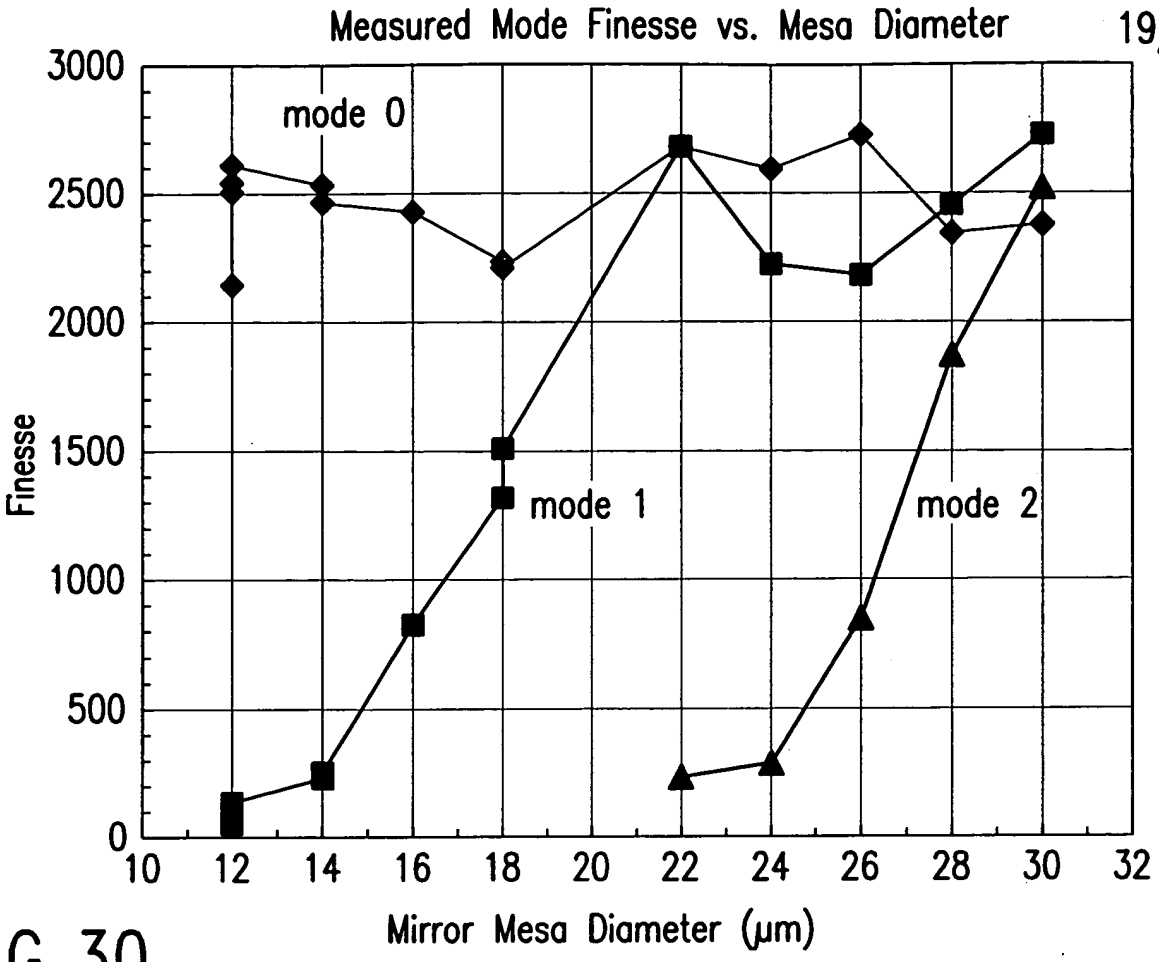
Measured Mode Finesse vs. Mesa Diameter
mode 0
mode 1
mode 2
Finesse
Mirror Mesa Diameter (μm)
3000
2500
2000
1500
1000
500
0
10
12
14
16
18
20
22
24
26
28
30
32

FIG. 30

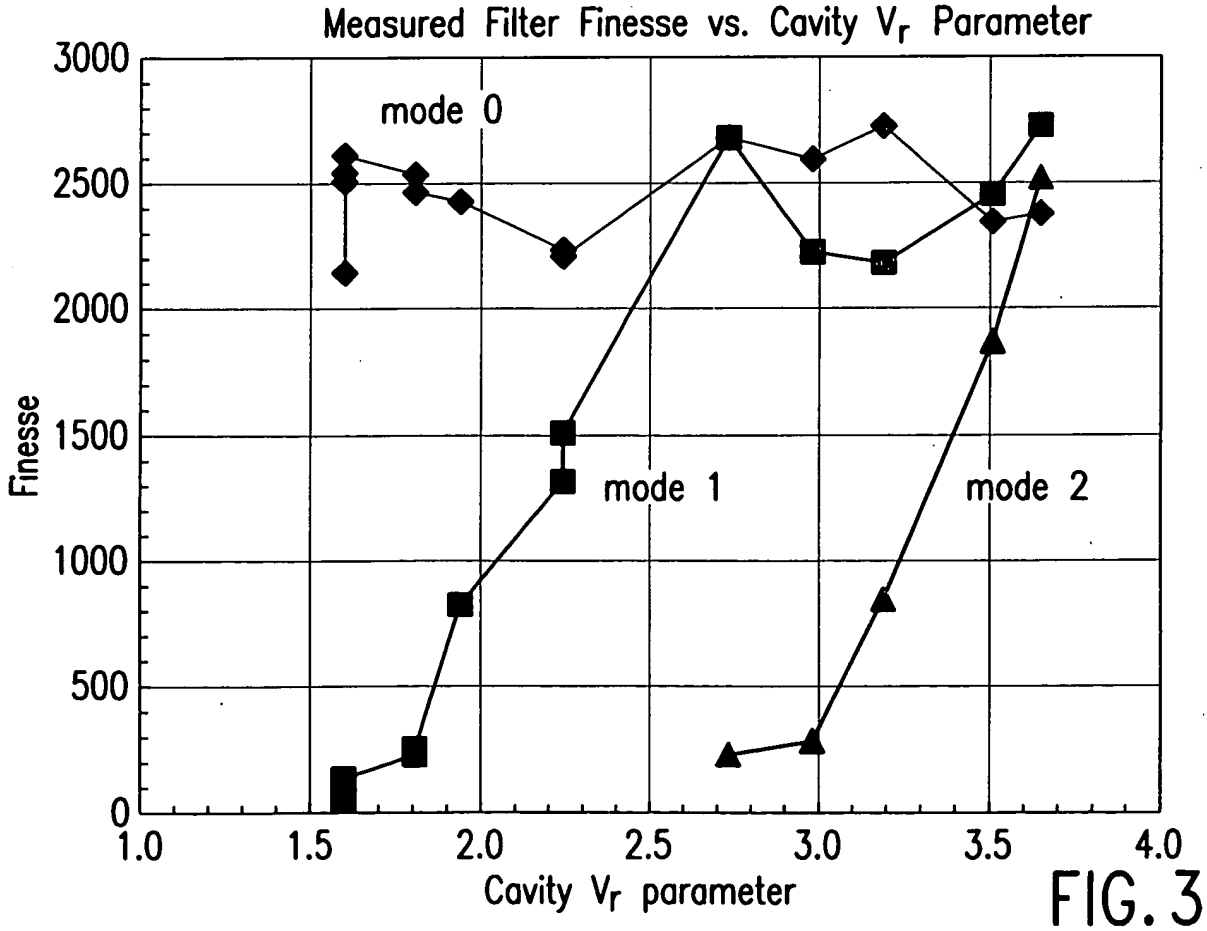
Measured Filter Finesse vs. Cavity V_r Parameter
mode 0
mode 1
mode 2
Finesse
Cavity V_r parameter
3000
2500
2000
1500
1000
500
0
1.0
1.5
2.0
2.5
3.0
3.5
4.0

FIG. 31

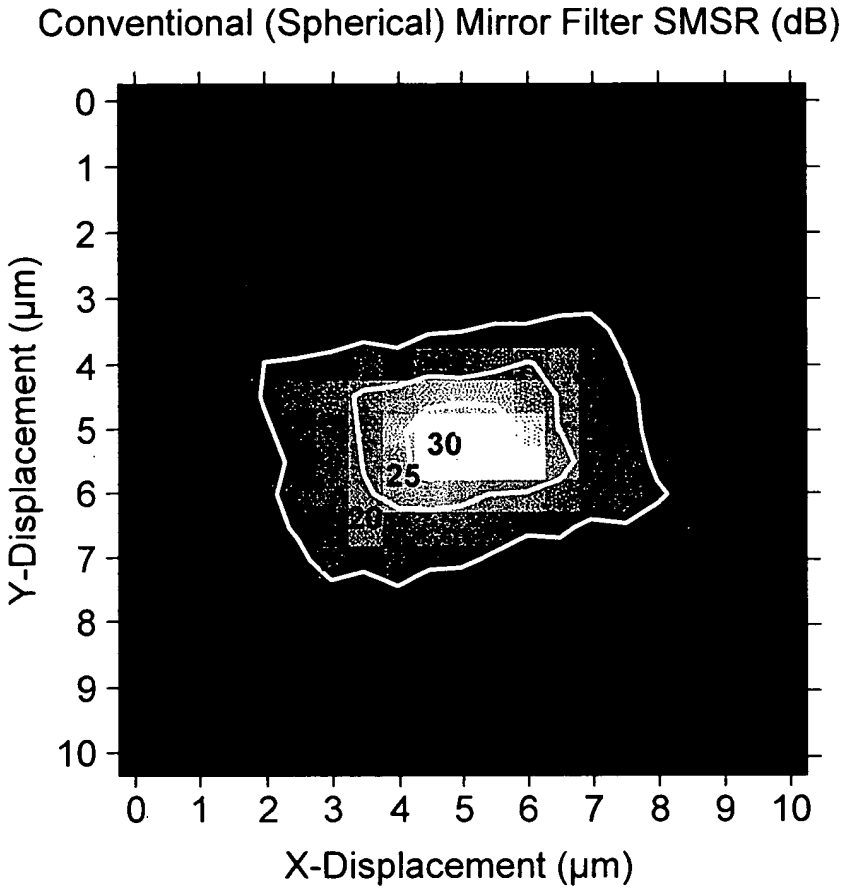
Conventional (Spherical) Mirror Filter SMSR (dB)
Y-Displacement (μm)
X-Displacement (μm)
0
1
2
3
4
5
6
7
8
9
10
30
25
20

FIG.32A

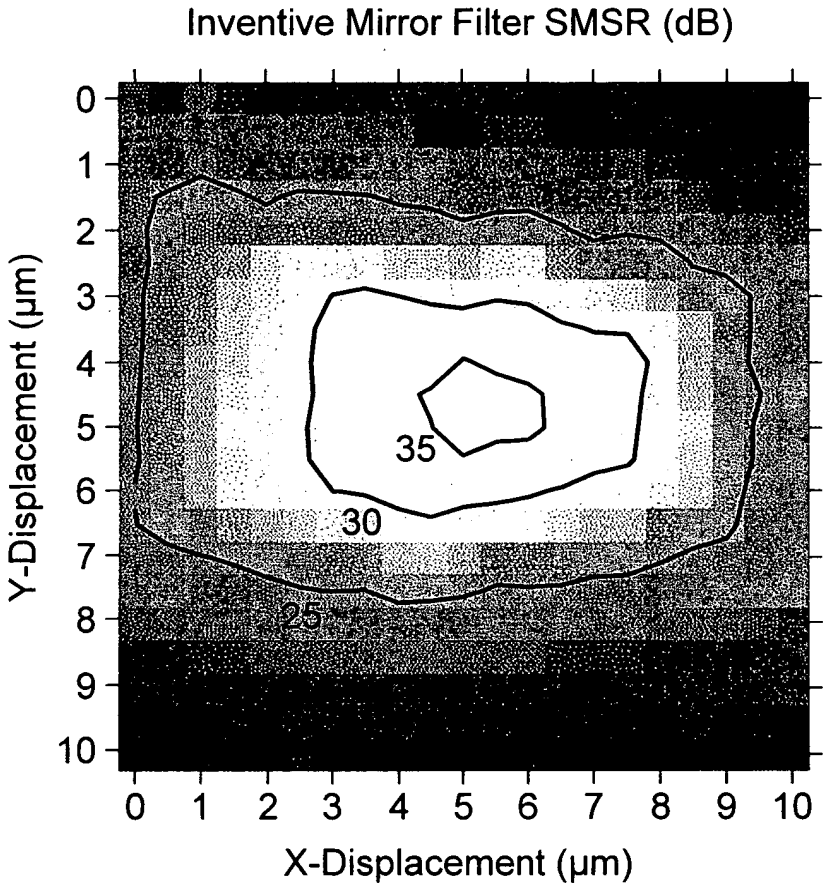
Inventive Mirror Filter SMSR (dB)
Y-Displacement (μm)
X-Displacement (μm)
0
1
2
3
4
5
6
7
8
9
10
35
30
25

FIG.32B

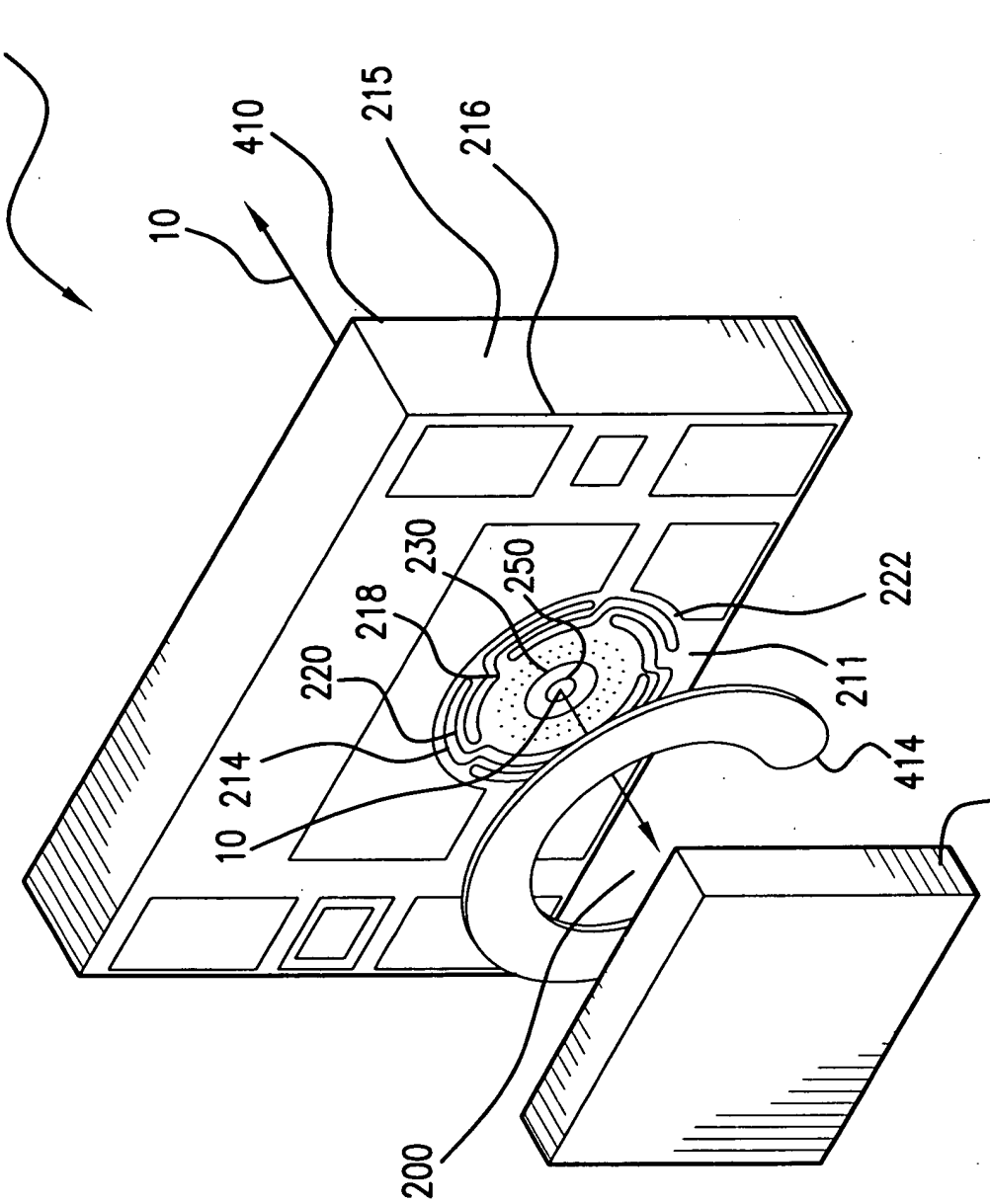

FIG. 33

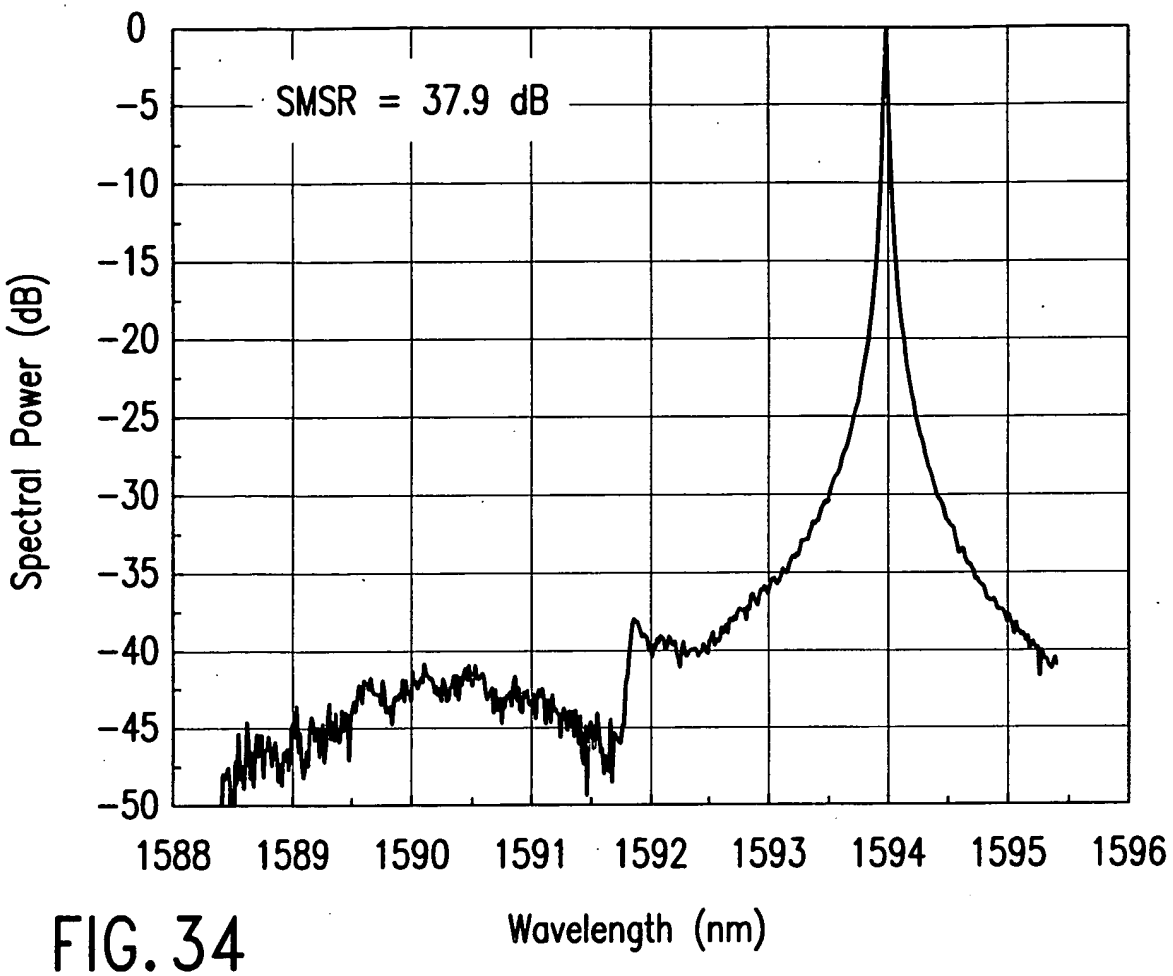
Measured Tunable Fabry–Perot Filter Spectrum
SMSR = 37.9 dB
Spectral Power (dB)
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
1588
1589
1590
1591
1592
1593
1594
1595
1596
Wavelength (nm)

FIG. 34

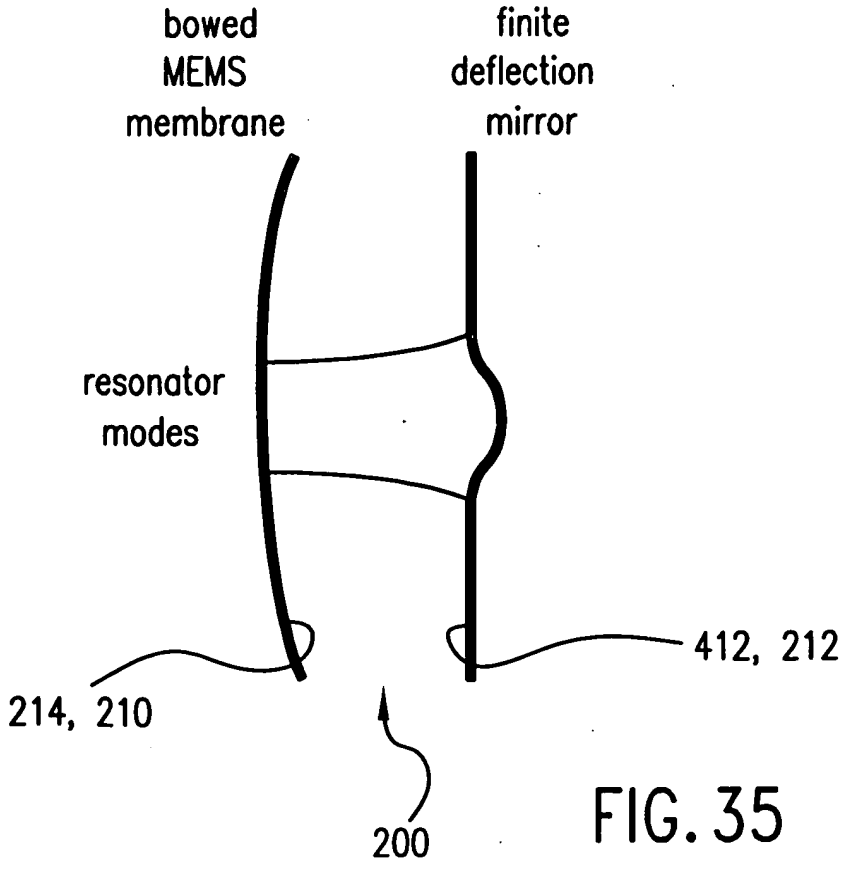
bowed MEMS membrane
finite deflection mirror
resonator modes
412, 212
214, 210
200

FIG. 35

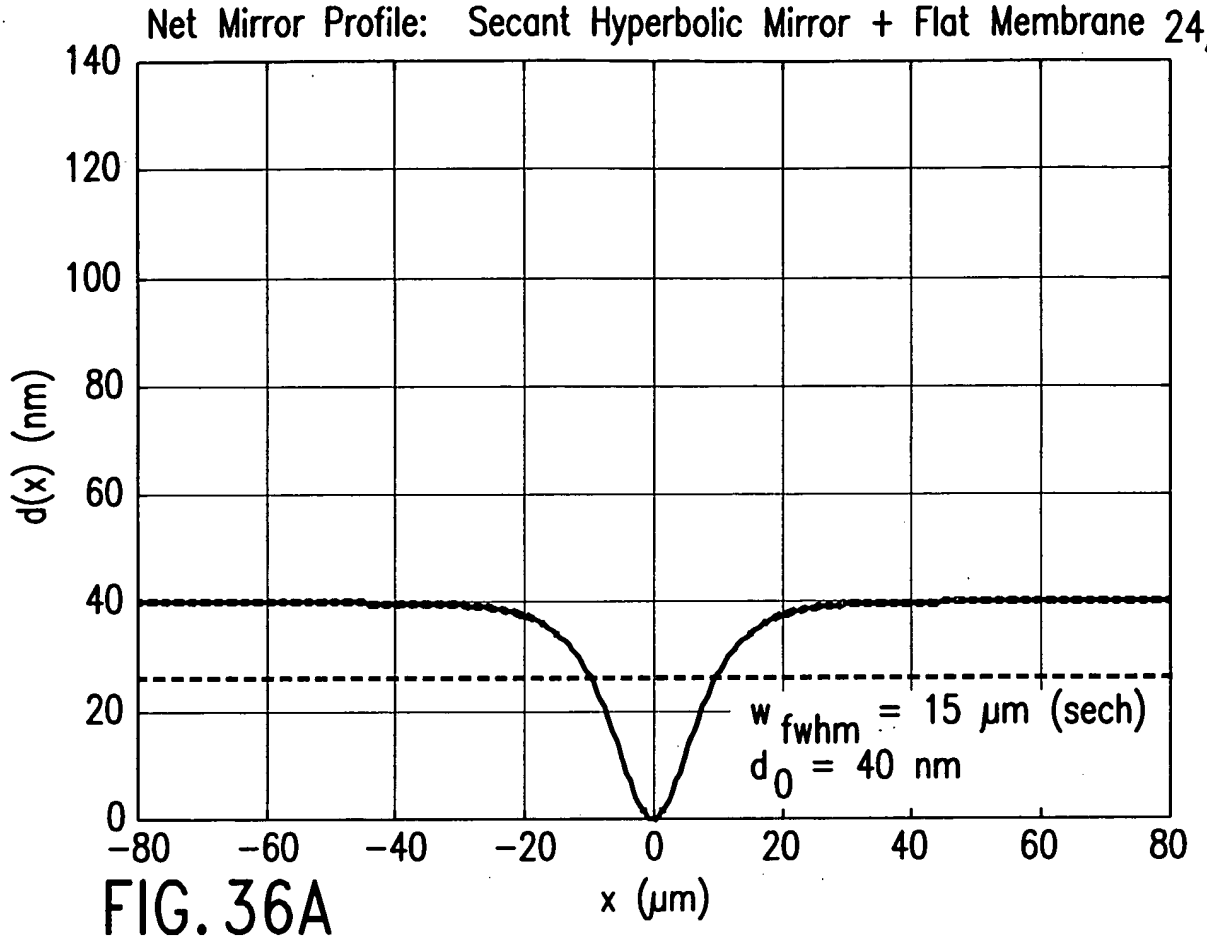

FIG. 36A

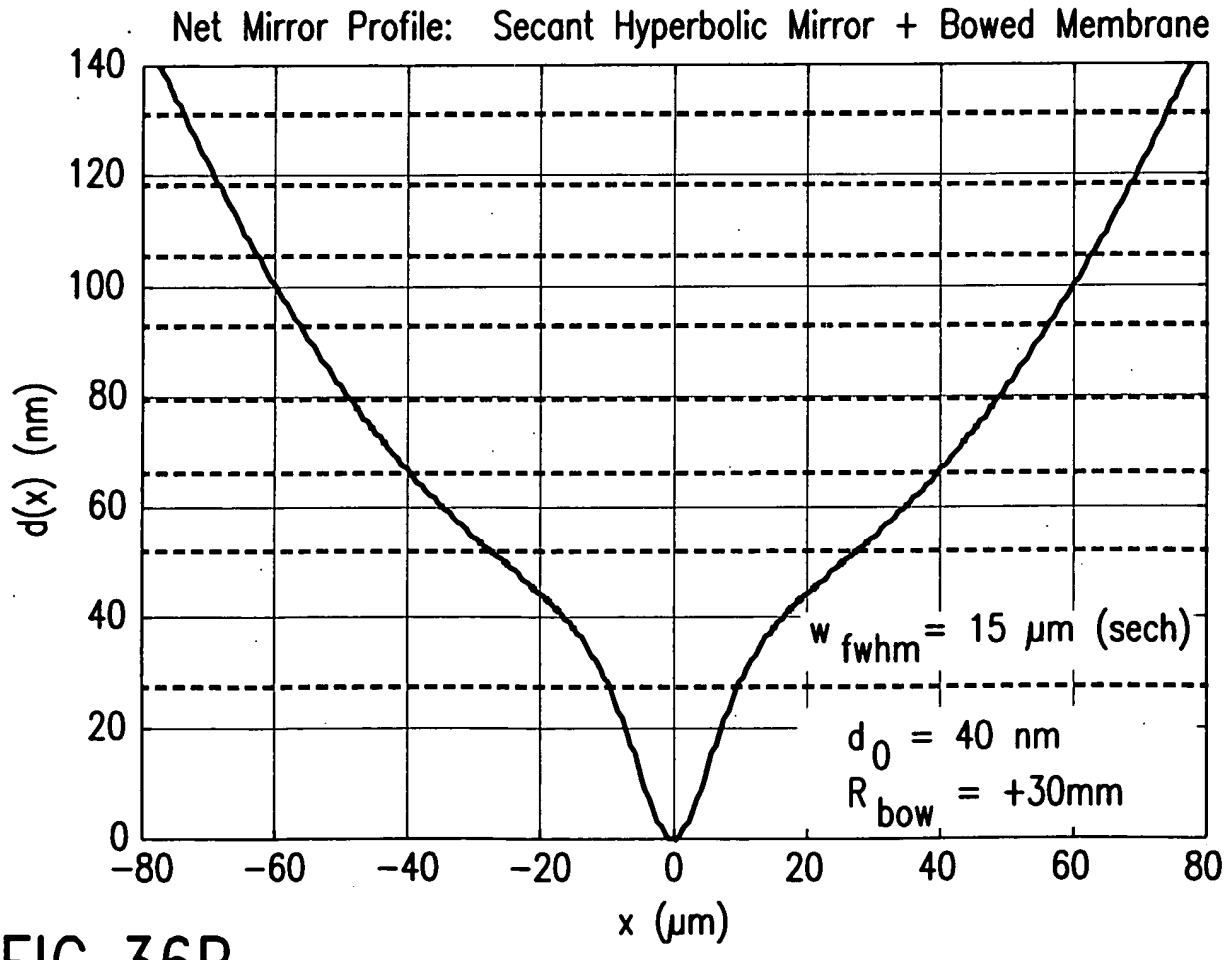

FIG. 36B

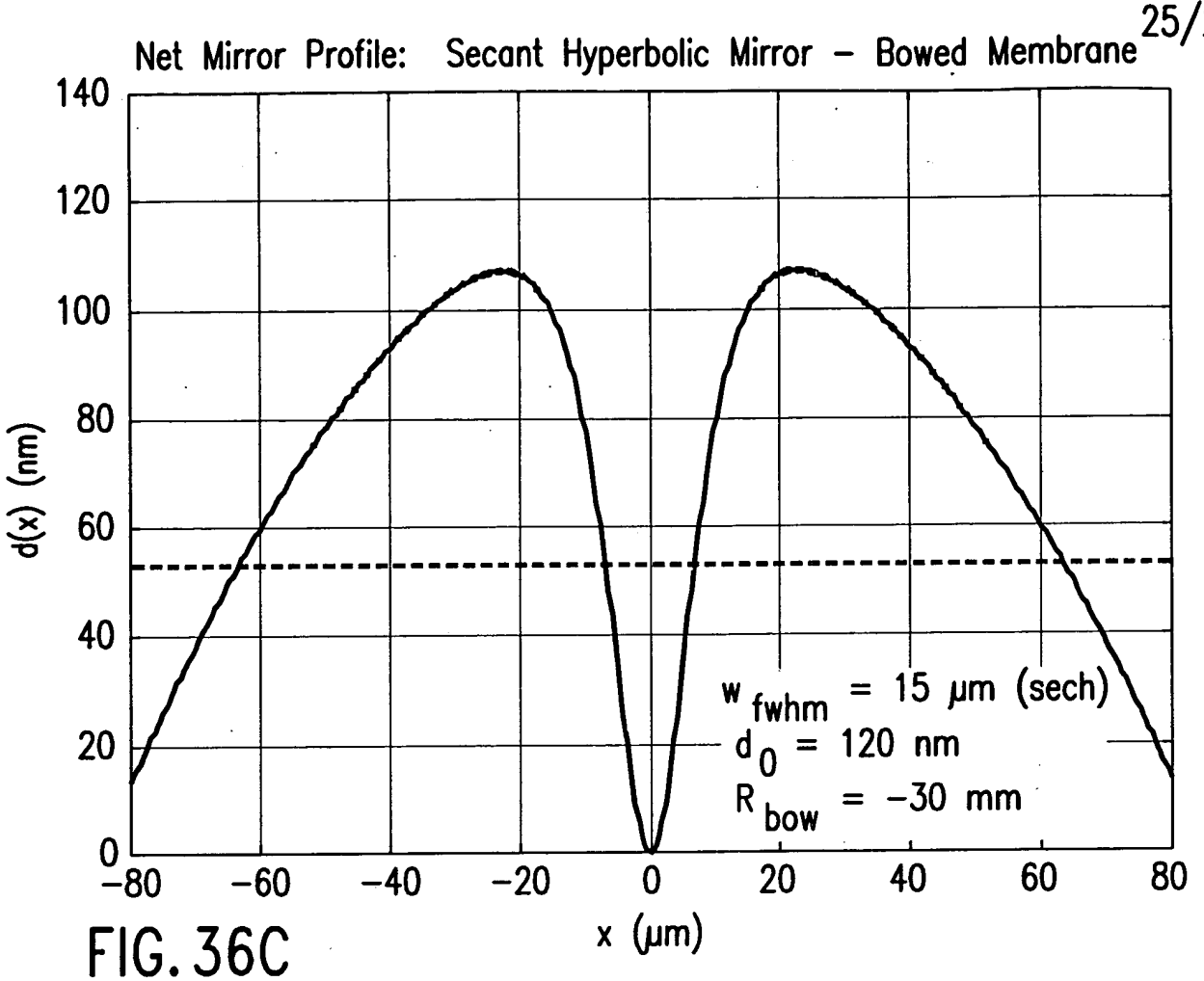

FIG. 36C

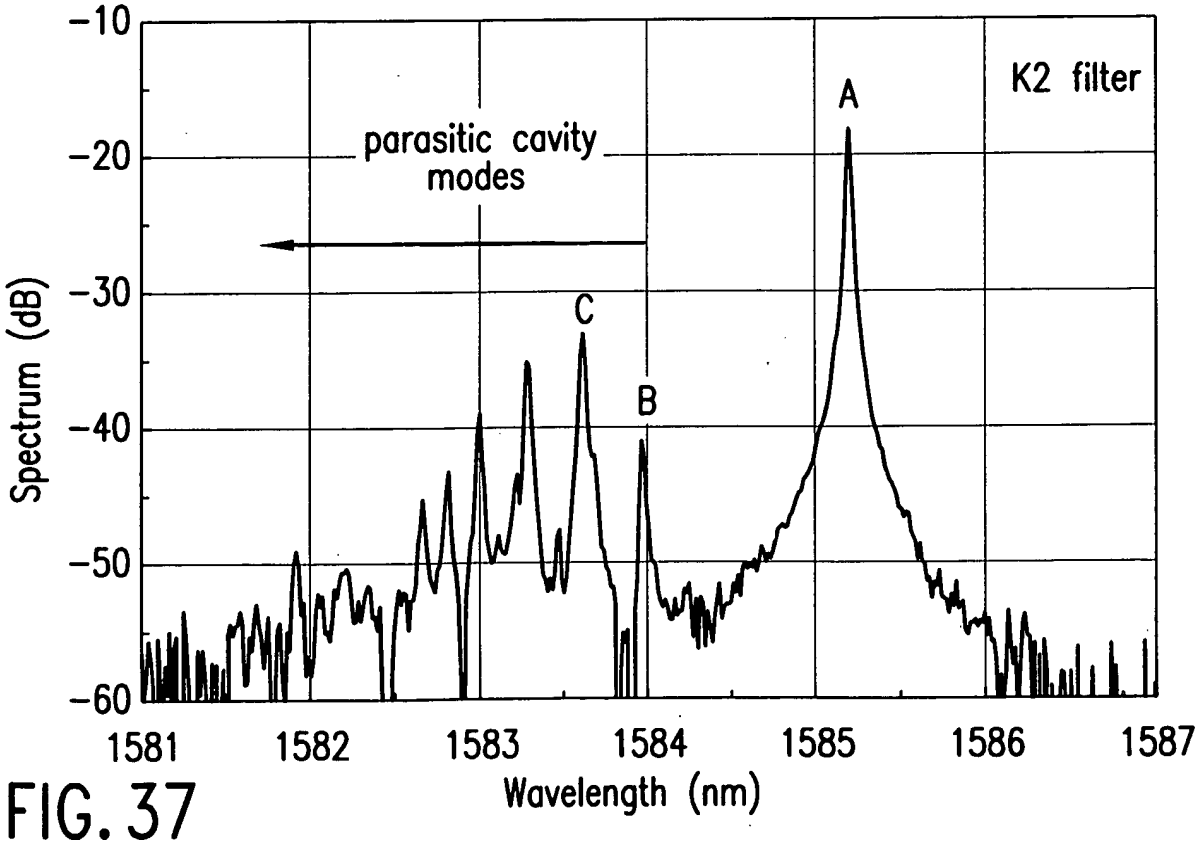

FIG. 37